

# Key-Specific Structure in Mozart's Music: A Peek into his Creative Process?

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**ABSTRACT:** Theories of tonal music take for granted that all keys of the same mode (i.e., all major and all minor keys) are employed by composers in essentially the same way; however, newer analytical and cognitive research challenges this view by pointing to aspects of transpositional nonequivalence among the keys. The present study offers possibly the first systematic, data-driven investigation of correlations between the choice of absolute key and structure across a composer's body of works. By performing an extensive corpus-based analysis of music by Wolfgang Amadé Mozart (1756–91), we derive 55 prototypes, subsuming phenomena from three independent domains: dynamic-rhetoric gestures that launch orchestral works, digressions to the parallel minor in sonata-allegro movements, and the occurrences of a particular six-note motive across Mozart's complete oeuvre. Ten prototypes display a significant association with a specific key after correction for multiple comparisons, amounting to a statistically significant total. Investigation of key-related musical structure offers fresh insight into Mozart's compositional decisions and the relation between schemata and their instantiations in his works, at the same time suggesting a revised perspective on traditional key characteristics. Mozart's perfect pitch offers one possible explanation for the role of key-related structure in his works; however, we also contemplate other possible explanations.

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GIVEN that every single piece of tonal music involves a choice of key, the question of the structural significance of a work's absolute key is potentially of all-embracing relevance. In reality, however, analytical endeavors addressing structural implications of the choice of key are strikingly sparse. To be sure, this is readily explainable by a general presupposition in modern music theory of transpositional equivalence among all major and all minor keys, an assumption sustained by a considerable volume of musical facts beyond the identity of interval structure among all twelve keys sharing the same mode. In the nineteenth century in particular, following the emergence of equal temperament and the constant technical improvement spanning all instrument families, composers were able to accomplish practically any technical and aesthetic feat with equal success in all keys. But even in earlier styles elements of musical structure were used largely independently of the choice of absolute key, with J. S. Bach's practice of transposing his concertos to a different key when arranging them for a different solo instrument being a convincing case in point.

However, we argue that this state of affairs does not necessarily boil down to transpositional equivalence among the keys. The following points outline several types of evidence suggesting that music of the common practice period is likely to exhibit an above-chance-level correlation between the choice of absolute key and musical content.

*Key characteristics.* While traditional approaches subsumed under the general concept of key characteristics (as explored, e.g., in Steblin, 1983) focus on musical expression and signification rather than structural features, musical semantics are, ultimately, primarily a corollary of the structure. This was the



working hypothesis of the German musicologist Paul Mies, who in 1948 published a systematic study of key-related characteristics in a selection of canonical works, focusing on Beethoven and Brahms. Proceeding from the assumption that a musical character is determined mainly by general attributes such as tempo, meter, and rhythm, Mies's results show only occasional correlation between the features explored and the choice of key. However, the existence of key characteristics as a field of music aesthetics and musical semantics championed by a number of influential composers and music theorists from the seventeenth through the twentieth century generally supports the idea of compositional differentiation among identically structured keys.

*Cognitive evidence.* Several empirical studies problematize the cognitive basis of transpositional equivalence, suggesting that an implicit form of absolute pitch representation is widespread. An ever-growing body of studies show that individuals devoid of explicit absolute pitch are able to distinguish between familiar melodies (or other familiar sounds) at their original pitch level and in transposition (e.g., Terhardt & Ward, 1982; Terhardt & Seewann, 1983; Schellenberg & Trehub, 2003, 2008; Smith & Schmuckler, 2008; Trehub, Schellenberg, & Nakata, 2008; Van Hedger, Heald, & Nusbaum, 2016), suggesting that implicit absolute pitch is widely prevalent among both musician and non-musician populations. Furthermore, a number of studies show that “white-key” pitches (as on the piano keyboard) entertain a processing advantage in trained listeners with and without explicit absolute pitch (Miyazaki, 1989; Takeuchi & Hulse, 1991; Marvin & Brinkman, 2000). Recent studies (Ben Haim, Eitan, & Chajut, 2014; Eitan, Ben-Haim, & Margulis, 2017) demonstrate that the processing advantage pertains in a more general sense to any more frequently occurring pitch classes as opposed to less frequent ones and is independent of formal musical training. Essentially, bias at the pitch-class level implies cognitive asymmetry among identically structured keys.

*Musical corpus studies.* Musical corpus research has been defined as “research involving statistical analysis of large bodies of naturally occurring musical data” (Temperley & VanHandel, 2013, p. 1). Only a relatively few studies to date have focused on the choice of absolute key as a factor affecting musical structure, and even fewer of these conform to the methodological standards required in present-day corpus research (cf. Huron, 2013). Wilhelm Gloede (1993) singles out certain motives as particularly typical of certain keys across Mozart's vocal and instrumental output; Steven B. Jan (1995) shows certain structural features to be particularly characteristic of Mozart's works in G minor; Mark Anson-Cartwright (2000) demonstrates that works in E $\flat$  major by Haydn, Mozart, and Beethoven share similar chromatic features, which differ substantially from the same composers' employment of chromaticism in a control key, D major. In a more recent study, Quinn & White (2017) demonstrate different distributions of scale degrees across different (structurally equivalent) absolute keys in a large corpus of tonal music, showing transpositional nonequivalence to possess statistical significance. The present research into key-related structural aspects in Mozart is possibly the first systematic, large-scale data-driven musical corpus study to date to address an assumed correlation between the choice of key and elements of the musical structure across multiple keys and divergent musical phenomena throughout a composer's body of works.

The widespread discourse of key characteristics, which emerged more or less simultaneously with the onset of the tonal era, attempted to account for the alleged differences among the then modern major and minor keys and instruct composers in their differentiated use. Notably, eighteenth-century composers and theorists often did not agree about the character of specific keys; nor was there general agreement regarding the import of key characteristics in the first place (Steblin, 1983). While Mozart's colleague Antonio Salieri reported that when composing his operas he would select an operatic number's key so as to match its dramatic content (Mosel, 1827), no such statement has been handed down to us from Mozart himself. In fact, the only first-hand account of Mozart's key choices, contained in a letter to his father in which he describes the work-in-progress on *The Abduction from the Seraglio* (Anderson, 1966, 2: p. 769), does not concern the character of any specific key, but rather the expression resulting from the juxtaposition of two keys a major third apart (F major and A minor). Arguably, this passage suggests that Mozart construed musical expression as a corollary of structural factors rather than the choice of absolute key.

In spite of the meagerness of primary source evidence, twentieth-century music research witnessed a considerable array of publications on key characteristics in Mozart's music. Triggered by Werner Lütthey's dissertation *Mozart und die Tonartencharakteristik* (1931), these publications (e.g., Hyatt-King, 1937; Chusid, 1968; Bockholdt-Weber, 2003) typically concentrate on the composer's vocal music, basing their conclusions on an interpretation of the lyrics and dramatic situations, rather than an analysis of structural features. Arguably, although very little evidence would suggest that Mozart ever consciously indulged in considerations of key characteristics, one cannot preclude that at least some of his key choices were semantically motivated, such as, for instance, in his symbolic employment of the “Masonic key” E $\flat$  major in

*Die Zauberflöte* and other Masonic works (cf. Elenor, 1987; Kronos, 1993), or the use of specific keys in conjunction with particular aria types (cf. Webster, 1991). However, a more recent research attitude chooses to focus on structural aspects that are demonstrably shared among pieces in the same key, notable examples being Gloede, 1993; Jan, 1995; and Anson-Cartwright, 2000, mentioned above. While no downright contradiction exists between this structure-driven attitude and traditional key characteristics, the two approaches address essentially different aspects of key-relatedness.

Taking all this into consideration, we argue that structure-driven analysis possibly represents a more adequate framework for approaching the role of key choice in Mozart's music than traditional key characteristics. In our present investigation, we refrain from using the semantically connoted term "key character," choosing, instead, to refer to the tokens of key-related structure to be explored as "key-related idioms." We propose that although the difference between Mozart's output, say, in C and in D major does not seem to suggest two different musical "languages," works in specific keys nonetheless evince particular structural attributes that may be likened to an idiomatic dialect.

Whereas every tonal composer is prone to develop some kind of association between the choice of key and musical matter—merely by having to formulate her or his musical ideas in specific keys—key-related compositional habits are especially likely to evolve in composers possessing absolute pitch, owing to their pitch-related and—by implication—key-related cognitive predisposition (Schlaug, Jancke, Huang, & Steinmetz, 1995). Mozart was probably the most famous historical possessor of absolute pitch, with several anecdotes documenting his ability as a child prodigy not only to label pitches, but also to detect minute deviations from the pitch system he was accustomed to. This motivated our choice of Mozart as a test case for the present pioneering study of key-related structure across a composer's oeuvre.

Incidentally, pitch was not fixed in Mozart's time. While the composer demonstrably possessed an exceptionally accurate absolute pitch, when he traveled (which he did a lot) he would encounter a different "A" pitch in different towns, with occasional fluctuations of over a semitone, and with many church organs still tuned to a substantially higher pitch level than the orchestral pitch standard used at the same location (Haynes, 2002). Any attempt to associate key-related phenomena in Mozart's music with the composer's sense of absolute pitch tacitly presupposes that individual pitches were represented in his mind in a more or less consistent manner, despite their highly divergent manifestations in the sonic reality of his time. Researchers generally concur that absolute pitch is acquired during a critical period in childhood (Deutsch, 2013; Levitin & Rogers, 2005). Hence, Mozart's mental "A" possibly originated from his early years in Salzburg.

In the following, after presenting our main research hypothesis we embark on a comprehensive analysis of selected structural features from three independent domains, supplying, in conjunction, the music-theoretical inferences and the statistical methods used. After presenting and discussing the analysis results, we proceed to examine several possible implications of our study for a more comprehensive understanding of Mozart's treatment of the keys and its contextualization in the compositional practice of his time.

## HYPOTHESIS

Our analysis addresses the question of a statistically significant association in Mozart's music between the occurrences of particular musical features and the choice of key. To achieve this, we set out to test the null-hypothesis that no such correlation exists. We consider a rejection of the null-hypothesis to indicate that Mozart's creative process was biased towards key-relatedness.

We proceed from the assumption that bias towards key-relatedness may manifest itself in any given feature of the musical structure, such as harmonic progressions, key-related rhythms, melodic motives, etc. We maintain that in order to convincingly establish key-relatedness as an underlying property of Mozart's music, one would need to assess key-related behavior across several different structural features. To this end, the present investigation takes a variety of musical phenomena into account, rather than concentrating on a single one. Ultimately, in our choice of investigated phenomena we attempt to cover a significant portion of Mozart's music—in terms of both the number of compositions included and the structural and perceptual salience of the phenomena examined.

Bearing these considerations in mind, we address three main domains of investigation, chosen to represent essentially different types of phenomena and cover a considerable part of Mozart's works. Our first domain of investigation—dynamic-rhetoric profiles in the opening themes of Mozart's orchestral works—encompasses 134 works for orchestra or large ensembles, amounting to well over 50% of his multi-movement

instrumental works. While considering only the opening theme of each cycle, we argue that these themes occupy a particularly significant position in the cycles they inaugurate. Our study of local digressions to the parallel minor in Mozart's sonata-allegro movements—the second domain of investigation—involves Mozart's 450 movements of the sonata-allegro type, amounting to a little less than a half of his roughly one thousand instrumental movements and standalone pieces. Instances of the phenomenon, totaling approx. 800, are found in over 60% of the movements analyzed (with often more than one instance per movement). Finally, in our study of melodic features we confine ourselves—for reasons to be discussed below—to the occurrences of one specific motive; however, these instances are gleaned from an examination of Mozart's complete vocal and instrumental oeuvre.

The availability of an ever-growing corpus of digitally encoded musical scores and the concurrent development of music information retrieval (MIR) techniques enable researchers to investigate correlational questions—such as the one addressed here—by applying advanced computational tools directly to note-level representations or audio data. However, our approach abides by more traditional music-analysis oriented corpus methods, based on defining and annotating individual occurrences of the musical features examined across the repertoire under investigation, subsequently testing for statistically significant correlations between particular features and specific keys.

Obviously, features defined in a broad, generic sense so as to constitute basic elements of Mozart's musical grammar occur too frequently in his music to allow for a statistically significant attachment to any particular key or keys. Hence, when proceeding from a highly general feature definition (which is, in itself, a desirable starting point in order to cover a reasonably large portion of Mozart's music), one would need to narrow down the investigated feature through additional specifications to attain a level of specificity at which a statistically significant association with specific keys may emerge. In the following subsection we discuss some general premises of our feature derivation, subsequently proceeding to flesh out individual feature definitions pertaining to each of the three main investigation domains mentioned above.

### Towards Defining Testable Prototypes

To illustrate the considerations that need to be taken into account in defining musical features for the present investigation, let us examine the following examples.



**Figure 1.** Mozart, (a) Piano Concerto in A major, K. 488, i, Allegro, mm. 1–4; (b) Clarinet Quintet in A major, K. 581, i, Allegro, mm. 1–4; (c) Clarinet Concerto in A major, K. 622, i, Allegro, mm. 1–4.



**Figure 2.** Mozart, (a) Oboe Concerto in C major, K. 314, iii, Rondo, Allegretto, mm. 1–4; (b) *Die Entführung aus dem Serail*, K. 384, No. 12, Aria (Blondchen), “Welche Wonne, welche Lust,” mm. 1–4.

All three beginnings subsumed under Figure 1 share the same opening gesture involving a descent from the fifth to the third scale degree in a moderate half-note pace (in the case of the Clarinet Concerto, the second half-note is shortened by an eighth note). Unassuming as it may seem, this opening gesture nevertheless enjoys maximum salience due to the primacy effect, occurring at a piece's very beginning (cf. Huron, 2001). However, a comparison with the two melodies subsumed under Figure 2, which begin with the same intervallic dyad, but in much quicker rhythmic values and as an anacrusis figure, emphasizes that melodic similarity also depends to a great extent on considerations of rhythm and metrical position. Proceeding from a basic feature defined in terms of, say, scale degrees or interval relations, one would obviously need to individualize this basic feature by imposing further typological specifications to attain a level of specificity at which concrete instantiations are capable of triggering a sense of similarity in listeners.

Our methodology proceeds along similar lines, starting from generic features, and subsequently adding several layers of specification so as to narrow down the corresponding occurrences to particularly similar ones. We refer to such complexes of musical features that subsume appreciably similar instantiations as *prototypes*. A prototype is derived from a certain cardinal feature through further specifications that either qualify aspects of the cardinal feature itself or combine it with other features.[2] Importantly, although prototypes represent abstract entities and should not be confused with their concrete instantiations, in the process of defining a prototype one also takes into account the real-world instantiations it subsumes. For instance, the three beginnings in Figure 1 are arguably heard as similar enough to justify defining a common prototype that subsumes all three. Such prototype definition would include—in addition to the melodic dyad  $\hat{5}-\hat{3}$ —a downbeat beginning, relatively broad rhythmic values and possibly also a temporal position at a movement's beginning.

Ultimately, our investigation has shown that several specification steps are required in order to generate prototypes that potentially are key-related. While there seems to be no way to tell in advance how many such steps and what types of specifications will be required to expose key-relatedness in a given repertoire, we argue that this apparent methodological caveat does not interfere with the validity of our argument. Key-relatedness in the sense investigated here is conceived of in terms of a network of associations in a composer's mind between musical content and keys. Since we possess no direct glimpse into Mozart's mind, our only way to access his private network of associations is by analytically assessing similarity among individual occurrences of a given structural feature. Whereas Mozart obviously wouldn't have associated basic, general features, such as the melodic dyad  $\hat{5}-\hat{3}$ , with any single key, we argue that by collecting all instances of a given general feature in a given corpus of works and grouping together instances that are particularly similar, the necessary conditions would be created for key-related prototypes to emerge, given that the musical corpus under analysis is characterized by an underlying key-relatedness. The fact that all three similar beginnings in Example 1, for example, share the same key, A major, suggests that a more comprehensive analysis might be able to establish a statistically significant association of their subsuming prototype with this key.[3] However, at a thus attained level of specification all relevant feature combinations must be evaluated to safeguard methodological consistency. For instance, the two beginnings in Figure 2, which may be subsumed under an anacrusis-based prototype, are in two different keys, C and G major, suggesting that *their* subsuming prototype, by contrast, is very probably not key-related.

### Dynamic-Rhetoric Opening Gestures in Works for Orchestra/Large Ensembles

In the seventeenth and eighteenth centuries, analogies between rhetoric and music permeated every level of musical thought (for example, Mattheson, 1739; Koch, 1782–93). Modern authors revisit the concept of “topic”—drawn from the classical rhetoric's “topos”—turning it into a cornerstone of a new, post-structuralist approach to musical semiotics and hermeneutics (e.g., Ratner, 1980; Agawu, 1991; Tarasti, 1994; Mirka, 2014). An important elaboration is the integration of the concept of musical gesture into theories concerned with musical meaning (e.g., Allanbrook, 1983; Hatten, 2004). Topics and gestures are construed as intersections between musical structure and semantics; sustained through cultural conventions, they are by definition publicly accessible, allowing for identification and signification among the members of a cultural community.

Eighteenth-century writers generally assign special importance to a musical composition's opening idea, as suggested by their use of the term “main theme” (It. “motivo principale” as in Galeazzi, 1791–96, Ger. “Hauptsatz” as in Koch, 1802). Music theorists of the time unanimously assert that the main theme exposes the chief character or expression of a musical piece as a whole and that it also supplies the most important musical material to be elaborated upon in the course of a composition. In a similar vein to the

leading role of the main theme within a movement, opening movements of multi-movement cycles are considered to occupy a conceptually prominent position within the cycles they inaugurate (Sulzer, 1771–1774, 2: col. 1122). Mozart would begin composing a multi-movement work as a rule at the beginning of the first movement, proceeding linearly (cf. Konrad, 2002, XVIII, fn. 36), meaning that the composition of the opening theme preceded and potentially influenced his work on the remainder of the cycle.

Mozart's 134 works for orchestra and large ensembles, whose opening dynamic gestures are often articulated additionally through instrumentation contrasts between full orchestra and partial orchestral forces, represent a particularly adequate repertoire for investigating issues of musical rhetoric. Our survey of opening themes includes symphonies, serenades, and concertos, corresponding to the Series IV–VII of the *Neue Mozart-Ausgabe* (1955–). As concert symphonies and opera overtures share historical origins and many genre-specific characteristics, we further include Mozart's overtures (several of which also exist in a concert-hall version) in the investigated work corpus.[4] We disregard slow introductions, found in some of Mozart's orchestral/ensemble works and overtures, and start our analysis at the beginning of the allegro section. Regarding concerto movements, notwithstanding the prominent role assigned in historical sources to the first solo entry (cf. Koch 1782–93, 3: p. 333), we regard in our analysis the primary theme as presented in the opening orchestral ritornello, rather than the first solo section.

The relevant section for analysis from each movement roughly corresponds to the primary-theme zone, allowing for cases where the latter consists of several thematic modules (cf. Hepokoski & Darcy, 2006, pp. 71ff.). Generally, the section for analysis is considered to end with the onset of the transition; however, in cases where the transition initially appears to continue the thematic presentation, we opt for including at least its beginning in the section for analysis. The analyzed section may occasionally conclude with a half cadence in the home key (rather than an authentic one on the home-key tonic), or even dissolve into a modulation to the secondary key. Supplementary Table S1 lists the sections for analysis for all 134 orchestral themes investigated.[5]

In our typology of dynamic-rhetoric opening gestures, we disregard concrete motives as well as the formal layout of the opening theme (e.g., sentential vs. period-like designs), focusing, instead, on what we consider to be general principles of musical rhetoric and, in particular, patterns of phrase repetition and contrast among phrases. Especially crucial for our prototype definitions is the use of dynamics and dynamic contrasts. The dynamic-rhetoric design of Mozart's orchestral opening themes is often complex, eluding a straightforward classification—our prototype definitions are chosen, among other considerations, so as to assign each of the movements under analysis (at least) one prototype. The individual prototypes derived in this analysis are listed in Table 1 and encompass the following categories:

*Antithetic prototypes.* Antithetic themes express contrast between two ideas or motives (cf. Gersthofer, 1993, pp. 32ff.), while at the same time employing contrasting dynamics (the dynamic contrast is as a rule sustained additionally—sometimes exclusively—through an alternation between full and reduced orchestral forces). Notably, in our typology this category refers only to themes starting with a loud statement and shifting to *piano* (regarding themes shifting from *piano* to *forte*, see prototypes of reinforcement below). We distinguish between two main categories of antithetic themes according to the use of harmonic and melodic sequences. On the one hand, there are sequenced themes, in which the entire antithetic complex (consisting of a *forte* and a *piano* element) is repeated a second time (rarely: a third time) on a different scale degree, as in the opening theme of the “Jupiter” Symphony K. 551 (see Figure 3a), where mm. 1–4 articulate a progression from the tonic to the dominant, and mm. 5–8 entail the opposite move from the dominant back to the tonic. On the other hand, there are non-sequenced themes, in which the antithetic complex is either stated only once, or repeated an additional time on the same scale degree (although not necessarily in a literal way). The non-sequenced category is further divided into symmetrical antithetic themes, with identically long *forte* and *piano* elements, and asymmetrical ones, with a longer *piano* element (as in Mozart's First Symphony, K. 16, see Figure 3b). Remarkably, all themes of the sequenced category are symmetrical (with the single exception of the opening theme of the Piano Concerto in C major, K. 503, see Figure 4 below), obviating a need for a further subdivision of this category.

**Figure 3.** Mozart, (a) Symphony in C major, K. 551, “Jupiter,” i, Allegro vivace, mm. 1–8; (b) Symphony in Eb major, K. 16, i, Molto allegro, mm. 1–14.

*Prototypes of cadential/postcadential reinforcement/decrease.* In Mozart’s orchestral themes that begin in *piano*, a concluding *forte* element seems to fulfill the role of an affirmative gesture, rather than that of a contrasting idea. We distinguish between two types of reinforcement prototypes based on the position of the *forte* gesture in relation to the cadence concluding the opening thematic module. If the *forte* element occurs in the course of preparing the cadence, we classify the theme in question into the prototype *cadential forte*. (In many themes, the initial presentation is repeated a second time, meaning that the affirmative gesture, too, occurs twice.) However, some opening themes have a particularly complex structure involving more than one thematic module—in such cases, the affirmative gesture may be postponed to a postcadential position with regard to the opening thematic module, and is accordingly classified under the prototype *postcadential forte*. (Consider, for instance, the primary theme of Mozart’s Eb-major Symphony K. 543, whose opening period in *piano* in mm. 26–54 is followed by a loud passage in mm. 54–71: as this latter passage concludes, once again, on the home-key tonic, we construe it as a codetta reaffirming the opening thematic presentation.) Importantly, only themes that persist in *piano* until the final affirmative gesture qualify for inclusion under the *cadential* and *postcadential forte* prototypes. However, we also allow for cases where the initial *piano* statement is preceded by a loud “curtain” figure, as in the case of the opening movement of the Oboe Concerto in C major, K. 314, where the “curtain” encompassing mm. 1–5 is organically integrated into the following thematic presentation in soft dynamics.[6]

A rather small number of themes evince an opposite dynamic scheme, starting in *forte* and dropping to *piano* just before the cadence. These themes are subsumed under the prototype of *cadential piano*, as, for example, in the case of the opening theme of the Bassoon Concerto in Bb major, K. 191 (see Figure 6c below). Even rarer are instances of the prototype *postcadential piano*, involving a dynamic decrease subsequent to the primary theme’s initial module’s closure (consider, e.g., the codetta-like *forte* passage in the first movement of the Divertimento in D major, K. 251, mm. 4–10).

*Prototypes involving thematic restatement in reverse dynamics.* Certain thematic presentations involve repeating the opening phrase or phrases in reverse dynamics—this either involves a soft presentation followed by a loud restatement (as at the beginning of the Symphony in A major, K. 201) or vice versa (as in the first movement of the Symphony in A major, K. 134). Of the latter type (shifting from *forte* to *piano*) there are only very few instances in the repertoire under investigation; as we construe these two types to incorporate essentially similar rhetoric strategies, we subsume them under a single prototype (see Table 1 below).

*Prototypes of interim dynamic shifts.* A number of themes involve repeating interim phrases (not the theme’s initial phrase) in reverse dynamics. In almost all such cases, this entails a repetition in *piano* of material initially presented in *forte*—accordingly, we choose to designate this prototype as an *interim echo*.

An echo as defined here may also involve repeating the same material on a different scale degree (as in the Concerto for Flute and Harp K. 299/i, mm. 7–10), or with other variants. Very rarely, the typical order of *forte* followed by *piano* is switched, resulting in an “inverse” echo (as in the Piano Concerto in E $\flat$  major, K. 482/i, mm. 27–31). We consider such cases to be similar enough to the generic echo to justify inclusion under the same prototype.

Occasionally, dynamic changes also occur in the middle of the musical flow. We distinguish two prototypes: one involving a non-gradual, *abrupt dynamic shift* from *forte* to *piano* or vice versa (as at the beginning of the Piano Concerto in F major, K. 413/i, at m. 3), and one involving a gradual *crescendo* based on the famous Mannheim tradition (as in the overture to the opera *La clemenza di Tito*, K.621, mm. 16–24). Finally, Mozart makes ample use of *fp* accents in his orchestral music to launch a work’s opening thematic statement. We consider this to represent a dynamic-rhetoric strategy in its own right, challenging the otherwise essentially binary distinction between loud and soft opening dynamics: for instance, *fp* accents may be used to launch themes that are otherwise throughout in *forte* (as in the case of the overture to *Mitridate*, K. 87), or throughout in *piano* (as in the Symphony in B $\flat$  major, K. 319/i). Instances of this prototype encompass cases of a single *fp* (or *sf*) accent, multiple accents in succession, or even quick alternations between short *forte* and *piano* elements, provided that the loud elements can be construed as written-out single-note accents (as in K. 319/i). Included are only cases where the accents in question occur directly at a theme’s beginning.

*Prototypes of uniform dynamics.* We distinguish two prototypes: a) thematic presentations that remain throughout in *piano* (as in the opening theme of the Piano Concerto in A major, K. 488); and b) thematic presentations that maintain a *forte* level throughout (see Symphony in G major, K.199/i, Figure 6b below—note that the opening theme of *Eine kleine Nachtmusik* shown in Figure 6a also constitutes an instance of this rule, albeit not a prototypical one, for reasons to be discussed below). Although maintaining a steady dynamic level throughout the opening thematic presentation may appear to represent a less specific strategy than the other dynamic-rhetoric prototypes discussed above, the two prototypes subsumed under this category nonetheless emerge as clearly profiled against the backdrop of the entire typology, with an only moderately large number of instantiations in the corpus under investigation: we classify a total of 21 opening themes into the *all-forte*, and 13 themes into the *all-piano* prototype (by comparison, the conceptually far more complex *asymmetrical antithetic* prototype subsumes no less than 20 themes).

Our investigation of opening dynamic-rhetoric profiles in Mozart’s cyclic orchestral/ensemble works yields 14 prototypes. Table 1 informs about the number of instances of each individual prototype. (See also Supplementary Table S1 for a detailed listing of all 134 opening orchestral themes alongside their individual prototype classifications; a legend connecting the prototype names in Table 1 and the machine-readable labels in the supplementary table is provided in Supplementary Table S5.)[5] An evaluation of the key-related idioms gleaned from this analysis is provided in the Results section.

**Table 1.** Prototypes of dynamic-rhetoric opening gestures and their instances in Mozart’s works for orchestra/large ensembles

Prototype	Instances in 7 common keys (in other keys)	Preferred Key (instances in key)	<i>p</i> -value	FDR corrected
Antithetic sequenced	6	C major (3)	0.189	0.387
Antithetic symmetrical non-sequenced	6	D major (3)	0.730	0.779
Antithetic asymmetrical non-sequenced	21	E $\flat$ major (9)	0.004*	0.023*
Cadential reinforcement	28 (1)	D major (12)	0.456	0.596
Postcadential reinforcement	4	D major (2)	0.755	0.789
Cadential decrease	10 (1)	B $\flat$ major (3)	0.493	0.621
Postcadential decrease	2	-	-	-
Thematic restatement in reverse dynamics	13 (3)	A major (4)	0.009*	0.043*
Interim echo	15	F major (4)	0.274	0.488
Mid-phrase abrupt dynamic shift	3	F major (2)	0.077	0.200
<i>Crescendo</i>	11 (1)	C major (4)	0.425	0.596
<i>Fp</i>	14	B $\flat$ major (4)	0.416	0.596

All <i>forte</i>	21 (1)	G major (8)	0.002*	0.019*
All <i>piano</i>	15	Bb major (4)	0.446	0.596

### Local Digressions to the Parallel Minor (“minorization”) in Sonata-Allegro Movements

We employ the term “minorization” in the sense of a local shift to the parallel minor key in contexts dominated by the corresponding major key. This term—uncommon in the English music-theoretical jargon—is used here to conflate procedures commonly designated as digression to the tonic minor on the one hand and modal mixture (typically involving lowering the sixth scale degree while retaining the major-mode tonic triad) on the other. In Western art music of the common practice period, and in particular in the pre-Classical and Classical repertoires, the minor mode is comparatively rare (Riley, 2014), making it semantically marked in comparison with the major mode, which serves as the default mode (cf. Hatten, 1994). Moreover, as early as Zarlino (1558), the minor mode is often connoted with sad or negative emotions (Aldwell & Schachter, 1989, pp. 19–20; Brover-Lubovsky, 2003; Grave, 2008). This expressive connotation is arguably culturally dependent rather than universal or natural, as it hardly seems to apply to earlier music or to the music of other cultures (Ball, 2008). Local shifts to the parallel minor in major-mode contexts, which are the object of our investigation, represent a highly common procedure in eighteenth-century music and later, and are also well documented in contemporary treatises (e.g., Riepel, 1752–86, 2: p. 66; Koch, 1782–93, 1: p. 196; Bach, 1753–62, 1: p. 109). Regarding the semantic content of this shift, Arthur Schopenhauer (1844, p. 296), among other writers, refers to pain and anxiety. Modern theorists generally consider digressions to the minor mode as a means of expressing a local collapse to negative emotions (e.g., Hepokoski & Darcy, 2006, pp. 307–10). Notably, Mozart’s use of minorization reveals a pronounced intensification tendency throughout his career—one that may give rise to an interpretation of his music as becoming more serious or even gloomier with time. However, this chronological tendency may also be accounted for by a general development in late eighteenth-century music towards greater harmonic complexity and a more intensive employment of chromaticism in general.

From a structural and formal perspective, minorization occurs in a great variety of manifestations. There is an essential difference, for instance, between semi-independent sections in the tonic minor (as, for instance, the A-minor episode in the rondo movement concluding Mozart’s Fifth Violin Concerto in A major, K. 291, mm. 132–262) and more local shifts occurring at the syntactical phrase-to-phrase level. Our present investigation is limited to movements of the sonata-allegro type: in this type of movements, only the local, syntactical type of minorization occurs.

Mozart’s pieces of the sonata-allegro type encompass 450 movements and standalone pieces throughout the composer’s career and across various instrumental genres. Besides generic sonata movements in allegro tempo, we include in this category any fast movements (or movements that fulfill a fast-movement function in a multi-movement cycle) adhering to Cone’s “sonata principle” (1968, pp. 76–77) in its commonly implemented sense (cf. Webster, 2001; Hepokoski, 2002). Marches are also included (as they incorporate a sufficiently elaborate secondary-theme area, as is required by the sonata principle), as are sonata-rondos, fast concerto movements in sonata and sonata-rondo form, opera overtures, and several additional instrumental movements (for a list of the movements included in this investigation, see Supplementary Table S4).[5]

Our investigation shows Mozart to employ minorization in pieces in all keys, albeit to a somewhat varying extent across different keys. Whereas minorization as a general phenomenon is not associated with any particular key, by defining more specific minorization prototypes, one may test for potential key-relatedness at the prototype level. Given the large number of minorization instances identified throughout our investigation—approx. 800—the need arises to split the corpus into a number of smaller corpora prior to generating testable prototype definitions. We opt for a preliminary classification according to the formal position across the sonata trajectory at which a minorization instance occurs. In our present study of minorization instances, we confine ourselves to three such formal positions: the primary theme, the secondary theme, and the beginning of the development section. Arguably, these formal positions possess maximal salience, as the primary and secondary themes constitute the most significant thematic presentations throughout a sonata movement, and the development’s beginning follows what is normally a sonata’s most pronounced interim caesura at the exposition’s end. With regard to minorization in the primary- and secondary-theme zone, we take into account double (or even triple) occurrences derived from the exposition and recapitulation sections, and—in concerto movements—the orchestral introduction.[7] However, such

multiple occurrences, inasmuch as they share identical or near-identical musical material, are subsumed under a single minorization instance, which, for the sake of analysis, inherits its features from all individual occurrences across the movement.[8] All instances occurring in a given movement are considered to relate to the movement's main key, even in cases where an individual instance occurs in relation to a different local key. (According to this principle, minorization instances occurring in minor-mode movements are associated with the minor key of the entire movement, although minorization by definition occurs in conjunction with a local major-mode key.) The 33 minorization prototypes derived are listed in Table 2 alongside data on the number of instances of each prototype and their association with particular keys; Supplementary Table S2 lists all 248 minorization instances participating in this analysis and their respective classifications (a legend connecting the prototype names in Table 2 and the machine-readable labels in the supplementary table is provided in Supplementary Table S5).[5]

**Table 2.** Minorization prototypes and their instances in Mozart's sonata-allegro movements, encompassing instances from the primary theme ("P"), the secondary theme ("S") and the development's beginning

Prototype	Instances in 7 common keys (in other keys)	Preferred Key (instances in key)	p-value	FDR corrected
P: tonic minor with AC	7	C major (5)	0.008*	0.039*
P: tonic minor with HC	9	D major (6)	0.026*	0.087
P: tonic minor cadence subverted	2	-	-	-
P: subdominant minorization: iv	12	F major (4)	0.175	0.374
P: subdominant minorization: ii <sup>7</sup> <sub>5b</sub>	4	C major (4)	0.002*	0.019*
P: subdominant minorization: bII/bVI	3	A major (2)	0.019*	0.073
P: subdominant minorization: bVI+	1	-	-	-
P: chromatically approached b3	4	D major (2)	0.705	0.771
P: chromatically approached b6	11	C major (6)	0.014*	0.058
P: minorization with lament bass	6	D major (4)	0.115	0.257
P: type 1 minor-mode echo	2	-	-	-
P: type 2 minor-mode echo	6	C major (3)	0.246	0.463
P: type 3 minor-mode echo	4	C major (2)	0.705	0.771
S: type 1 minor-mode echo	41 (1)	D major (18)	0.020*	0.073
S: type 2 minor-mode echo	27	A major (4)	0.280	0.488
S: type 3 minor-mode echo	19	C major (11)	0.000*	0.006*
S: reverse minor-mode echo	7	C major (4)	0.079	0.200
S: minor-mode consequent	8	D major (4)	0.443	0.596
S: minor-mode theme	11 (2)	A major (2)	0.502	0.621
S: unit's beginning in minor	19 (3)	D major (8)	0.342	0.536
Dev. beg.: modulation from v to ii	68	Bb major (13)	0.815	0.815
Dev. beg.: modulation from v to II	4	F major (4)	0.000*	0.006*
Dev. beg.: modulation from v to bIII	8	A major (2)	0.291	0.488
Dev. beg.: modulation from v to IV	3	F major (1)	0.646	0.741
Dev. beg.: modulation from v to iv	2	-	-	-
Dev. beg.: modulation from v to bVI	1	-	-	-
Dev. beg.: modulation from v to bVII	4	Eb major (4)	0.001*	0.008*
Dev. beg.: modulation from iii to bII	0 (1)	-	-	-
Dev. beg.: modulation from iii to vii	0 (1)	-	-	-
Dev. beg.: local subdominant minorization	6 (1)	G major (2)	0.318	0.515
Dev. beg.: targeting the minor subdominant	17 (1)	D major (7)	0.391	0.592
Dev. beg.: modulation from V to i	8	D major (5)	0.081	0.200

Dev. beg.: literal P restatement in minor	12	C major (6)	0.033*	0.102
Dev. beg.: non-literal P restatement in minor	20	C major (6)	0.586	0.707
Dev. beg.: major-to-minor P restatement	36 (1)	D major (11)	0.789	0.806
Dev. beg.: type 1 minor-mode echo	21	D major (8)	0.615	0.722
Dev. beg.: type 2 minor-mode echo	12	B $\flat$ major (5)	0.109	0.256
Dev. beg.: type 3 minor-mode echo	7	B $\flat$ major (4)	0.044*	0.128

In what follows, we provide some details regarding the minorization prototypes shown in Table 2.

*Minorization instances in the primary-theme zone.* We located a total of 32 minorization instances in the primary-theme zones of 29 of the movements under investigation, and derived 13 prototypes into which we classify the individual instances, occasionally opting for multiple classification. We thereby took into account only instances that involve minorization in conjunction with the piece's tonic key.[9]

*Minorization instances in the secondary-theme zone.* Delineating the secondary-theme zone proves particularly tricky, because elements of the secondary theme proper may often be confused with post-modulation transition modules on the one hand and closing-zone modules on the other, due to the fact that all thematic modules in question are in the secondary key.[10] With this in mind, we choose to consider the exposition's entire secondary-key area as potentially incorporating instances of minorization in conjunction with the secondary theme; however, we focus on a selection of prototypes particularly characteristic of the secondary-theme zone proper (see details below), disregarding instances that do not fall under the selected prototypes. As a result, our selection of seven prototypes of minorization in the secondary-key area covers only part of the minorization instances related to the secondary theme, but on the other hand it adds several instances that occur in the secondary-key area but arguably outside the secondary-theme zone.[11] All in all, our analysis spans 94 instances derived from 84 individual movements—a substantially larger corpus than the one gleaned from the primary-theme zone. In analogy to our analysis of minorization instances from the primary-theme zone discussed above, we subsume corresponding occurrences from the exposition, the recapitulation and (in concerto movements) the orchestral introduction under one conflated minorization instance, taking into account only minorization instances in conjunction with the piece's secondary key (in the exposition), or tonic key (in the orchestral introduction and recapitulation).

*Minorization instances at the development's beginning.* Given that the phenomenon investigated—minorization—is a tonal-harmonic one, we define the third formal position addressed in our investigation—the development's beginning—mainly according to tonal-harmonic criteria. Bearing in mind that sonata developments almost invariably commence in the secondary key (or, occasionally, in the home key, when the exposition ends with a retransition), we construe the development's beginning to stretch from the exposition's end (i.e., following the double bar, where one exists) to include any passages occurring prior to the first change of key (which may occasionally occur well into the development section, such as in cases where the development starts with a new theme in the secondary key). Remarkably, 118 movements (over a quarter of the movements examined) entail minorization at the development's beginning. The key distribution among these instances is nearly identical with that of the entire corpus under examination, indicating that minorization at this formal position is, as such, not key-related. However, some of the 18 prototypes derived through additional specifications are related to specific keys at a statistically significant level (see Results section).

We proceed with an account of the individual minorization prototypes derived across the three formal zones specified above.

*The harmonic degrees involved in the minorization.* Following an established analytical practice, we distinguish between two main types of shift to the parallel-minor key: minorization of the tonic and of the subdominant. The first type involves transferring the tonic triad to the minor by lowering the third scale degree, at the same time implying a comprehensive local digression to the minor mode. The other type is a weaker, partial variant of the phenomenon involving transferring only degrees with a subdominant function to the minor mode by lowering the sixth scale degree (occasionally lowering additional scale degrees, such as the second scale degree in the Neapolitan sixth chord), while leaving the tonic triad in the major mode. This latter procedure is often referred to as “modal mixture” (cf. Aldwell & Schachter, 1989, pp. 390ff.). As an illustrative example, consider the opening theme of Mozart's Piano Concerto K. 503 (Figure 4): on the fourth beat of m. 6, Mozart introduces a single-chord minorization of the harmonic second degree, whereas at m. 17 he embarks on an extensive passage in the tonic minor, in the course of which the stability of the

local minor key is demonstrated by tonicizing its relative major, E $\flat$  major, at m. 23. Although in the passage shown in Figure 4 the minorization of the subdominant and that of the tonic materialize as two separate instances, Mozart often proceeds within a continuous stretch of music from the weaker, subdominant variant to the stronger one that involves the minor-mode tonic. The distinction between tonic and subdominant minorization is crucial for our individual prototype definitions, but in some cases additional specifications are required. For instance, when classifying cases of minorization of the subdominant in the primary-theme zone, we take into account the exact harmonic degree that receives the lowered sixth scale degree (e.g., the half-diminished second degree, as in Figure 4, m. 6, etc.).

The figure displays a musical score for Mozart's Piano Concerto in C major, K. 503, i, Allegro maestoso, measures 1–26. The score is in 2/4 time and features an orchestra, Oboe (Ob.), Bassoon (Bsn.), and Stradivarius (Str.). The music begins with a forte (*f*) dynamic. A bracket labeled "Type 2 minor-mode echo" spans measures 15–18, indicating a minorization of the preceding major-mode material. A "digression to the tonic minor" is marked above measures 23–26. A box in measure 6 highlights a half-diminished second degree ( $ii^7_{sb}$ ).

Figure 4. Mozart, Piano Concerto in C major, K. 503, i, Allegro maestoso, mm. 1–26.

*Phrase repetition in minor* (“minor-mode echo”). Many individual instances of minorization involve restatement of major-mode elements in minor. We subsume such cases under the general concept of “minor-mode echo” (cf. Gersthofer, 1993, pp. 211, 215), notwithstanding that—unlike the generic echo—phrase repetition in the minor-mode does not necessarily involve softer dynamics. We distinguish three main types of echoes, corresponding to three basic possibilities of assembling major- and minor-mode elements into syntactical units, keeping in mind that minor-mode echoes essentially preserve the original pitch material while transferring only the relevant scale degrees to the minor mode. A type 1 echo refers to cases in which the beginning of a syntactical unit (e.g., a theme) is subsequently repeated in minor.[12] A type 2 echo refers to the minorization of a continuation element—that is, an element located at a syntactical unit’s interim position—whereby the minor-mode variant directly follows the respective major-mode original.[13] This is the echo type found, for instance, in mm. 15–18 of the first movement of the Piano Concerto K. 503 (see Figure 4), with mm. 17–18 constituting a minor-mode variant of the preceding two measures. In a similar vein to type 2, type 3 echoes also involve minorization of interim elements; however, the minor-mode restatement does not follow the major-mode original directly, but rather at some distance (see Results section and Figure 8 below).

Minor-mode echoes in the secondary-theme zone are found to occur in several more specific designs in a way that justifies deriving a number of additional echo-related prototypes. In all such cases, we opt for a double classification of the instances in question, classifying them under both the main echo type they pertain to (“1,” “2,” or “3”) and the more particular prototype. A more specific subtype of the type 1 echo involves period-like themes whose consequents (following the half cadence at the antecedent’s end) begin in the minor mode, typically also remaining in minor throughout (prototype: *minor-mode consequent*—see, e.g., “Prague” Symphony, K. 504, first movement, mm. 105ff., 252ff.). While minor-mode echoes typically refer back to a preceding major-mode element, in some rare cases the order of events is reversed, such that the minor-mode element occurs first, giving rise to the prototype *reverse minor-mode echo* (see, e.g., the finale of the “Coronation” Concerto K. 537, mm. 89ff., 240ff.—admittedly, the term “minor-mode echo” may appear questionable in this context, given that it is rather the major-mode element that echoes the minor-mode one).

*Tonal embedding of the minorization instance.* Depending on the formal position at which the shift to the minor mode occurs, the tonal settings surrounding a minorization instance justify deriving a number of additional prototypes to achieve a more comprehensive characterization of individual instances. In the primary-theme zone, we distinguish three prototypes involving minorization of the tonic degree based on the type of closure attained during (or subsequent to) the minor-mode passage. The first prototype subsumes instances that encompass (or culminate in) an authentic cadence (prototype: *tonic minor with AC*—see, e.g., K. 503/i, mm. 17–26 in Figure 4; note that in this case, the cadential arrival in m. 26 is elided with a return to major). Alternatively, passages in the tonic minor often culminate in a half cadence (*tonic minor with HC*), and, in some rare cases, they are aborted midway for the sake of tonicizing a non-tonic degree (*tonic minor cadence subverted*).

Minorization instances located at the development’s beginning typically initiate a modulatory process marking the onset of the development’s core (cf. Caplin, 1998, pp. 139ff.). Accordingly, we construe the subsequent tonal goal following the minorization (whether this goal is actually attained or only sufficiently clearly tonicized) as a crucial typological criterion, giving rise to eleven prototype definitions. In major-mode movements, the most common modulation goal following a minorization of the dominant key at the development’s beginning is the minor key of the second degree (with regard to the movement’s home key), a constellation we subsume under the prototype *modulation from v to ii*. With numerous instances in movements in all keys, this prototype evinces no key-specific preferences.[14] By contrast, some of the prototypes involving less common post-minorization modulation goals (such as bVII) are strongly associated with a specific key (see Results section). Local minorization of subdominant degrees may occur at the development’s beginning (like elsewhere in the movement) without modulatory consequences—we subsume such instances under the prototype *local subdominant minorization*. However, the minor-mode subdominant key may also become the target of a modulatory process, engendering two additional prototype definitions: the first one (*targeting the minor subdominant*) involves turning the development’s initial major-mode key into the dominant of a minor-mode key located a fifth below (typically, this boils down to transforming a piece’s dominant key to the dominant of the tonic-minor key); the second one (*modulation from V to i*) subsumes instances that proceed from the major-mode dominant (V) to accomplish a full modulation to the tonic minor (i), thereby launching a new syntactical unit in this key.[15]

*Additional structural attributes of shifts to the parallel minor.* The following prototype definitions are gleaned from the concrete corpus of instances, by taking into account additional relevant features.

1. Chromatically approached lowered tones. The lowered third and sixth scale degrees, which are the characteristic tokens of a minorization of the tonic and the subdominant, respectively, may be approached either diatonically or chromatically. The latter possibility has a pronounced poignant note, as the original major-mode pitch class and its lowered variant clash together in direct proximity (see transition between mm. 16 and 17 in K. 503/i, Figure 4). Particularly in the primary-theme zone, a considerable number of instances involve introducing the lowered tones chromatically, justifying the derivation of corresponding prototype definitions.

2. Minorization in connection with the lament-bass figure. Some of the instances derived in the primary-theme zone incorporate this figure, marked by a long-lasting topical association with the expression of mourning and anguish (cf. Williams, 1998; Caplin, 2014). The presence of the lament-bass figure in the primary-theme zone—not necessarily in the bass part, and occasionally in an incomplete form—gives rise to a corresponding prototype definition (see, e.g., the overture to *Idomeneo*, mm. 10–15).

3. Minorization at a syntactical unit’s beginning in the secondary-key area. In the vast majority of cases, the minor mode emerges in the middle of a syntactical unit. However, in the secondary-key area, the

shift to minor occasionally coincides with a syntactical unit's beginning, a constellation that grants it particular salience. We distinguish two prototypes: one involving veritable minor-mode themes (such as the tuneful one in the third movement of the Clarinet Concerto K. 622, mm. 73ff.), and another, less-sharply defined prototype that encompasses any syntactical unit's beginning in minor (as this prototype subsumes varying levels of thematic distinctness, we classify into it also the particularly distinct minor-mode themes of the preceding prototype).

4. Reference to the primary theme at the development's beginning. Quoting the primary theme at the beginning of the development section is a highly widespread procedure in sonata movements of the Classical period, considered, for instance, by Hepokoski and Darcy (2006, p. 205) to represent a "first level default." In a number of sonata developments, this procedure coincides with a shift to the parallel minor so as to launch the development with a minor-mode restatement of the primary theme (most typically in the dominant minor key). We distinguish three prototypes corresponding to three levels of distinctness. The first prototype involves a *literal primary-theme restatement in minor* (which may be very concise and, occasionally, near-literal rather than literal); the second prototype involves a non-literal employment of material derived from the primary theme's beginning, introducing significant changes to the theme's texture, dynamics, motives, etc.; the third prototype subsumes cases where the primary theme's restatement begins in the major and only subsequently shifts to the minor mode. As we construe the three prototypes to represent decreasing levels of distinctness, each of the less distinctive prototypes (*non-literal primary-theme restatement* and *major-to-minor primary-theme restatement*) also subsumes the instances of the more distinctive ones.

### Occurrences of the "Tamino" Six-Note Motive in Mozart's Complete Works

The motive we name here after Tamino, the hero of Mozart's *Magic Flute*, could be named just as well after Ilia, one of the main female protagonists of *Idomeneo*, since it also figures in her lyrical aria in the second act of that opera (see Table 3 below). In fact, Alfred Heuß (1930, 188f.) specifically refers to this motive as a "genuine E-flat idea," owing to its occurrences in Mozart's (and other composers') works in this key.

In order to gain insight into the special methodological difficulties in connection with melodic prototypes, it is necessary to return to Figures 1 and 2 presented above. The similarity between the three melodies subsumed under Figure 1 involves surface-level identity of the opening melodic gestures. Figure 2, on the other hand, is comprised of two melodies whose first halves (up to the middle of m. 2)—while traceable to a common melodic skeleton—are only loosely associated with one another at the surface level. Only in their second halves do these two melodies converge also at the surface level.

Notably, Figures 1 and 2 exemplify two different types of intertextual cross-relations. While the three themes in Figure 1 incorporate instantiations of a common opening melodic prototype, the melodies in Figure 2—notwithstanding their divergent first halves—constitute obvious quotations of one another, or, more precisely, Mozart borrowed the tune of Blondchen's joy aria—with some modifications—from the finale of his own earlier oboe concerto. Unsurprisingly, whereas melodic prototypes—such as the one subsuming the three themes in Figure 1—may resurface in a considerable number of compositions, more comprehensive melodic borrowings of the type demonstrated by Figure 2 are limited to a few instantiations only.[16] When setting out to trace statistically significant correlations between recurrent melodies and the choice of key, one would obviously opt for the first category of melodic prototypes.[17] In conjunction, Figure 2 also illustrates the particular methodological challenges involved in assessing similarity among melodies that differ from one another at the surface level: while the first halves of the two themes may be reduced to their melodic skeletons in a number of ways, only certain reductions will trace them back to a common skeleton. Owing to the methodological difficulties involved in handling the relationship between melodic surface and underlying skeleton, we opt for defining the motive to be investigated directly at the surface level.[18]

Figure 5a presents a layer analysis of the "Tamino" motive, showing the tonic scale degree (tones 1 and 4 of the sequence) to act as an implicit upper pedal note maintained throughout the motive's duration and tones 2 and 5 to represent chromatic appoggiaturas to the structural tones 3 and 6, which articulate, in turn, a descent from the sixth to the fifth scale degree. By searching Mozart's complete works in all genres for instances, we located eight literal occurrences of this motive as displayed in Table 3. Figure 5b shows what is probably the motive's best-known occurrence in Tamino's "Portrait Aria." On the other hand, Figure 5c taken from the slow introduction to the first movement of the String Quartet K. 171 is exceptional in that it is the only motive instance starting on a downbeat and exhibiting a unison texture. While identical with the

other instances at the melodic surface level, K. 171/i does not correspond to the layer analysis proposed in Figure 5a, exemplifying instead a divergent voice-leading schema.[19]

(a) Musical notation showing a six-note motive with layer analysis numbered 1 through 6.

(b) Musical score for Tamino (vocal line) and Orchestra. The vocal line includes the lyrics: "Dies Bild-nis ist bezahemdschön, wie noch keinAuge je ge - seh'n. Ich fühl' es, ich fühl' es, wiesies Göt - tebild mein Herz..."

(c) Musical score for String Quartet in Eb major, K. 171, i, Adagio introduction.

(d) Musical score for Oboe and Strings in Oboe Quartet in F major, K. 370, i, Allegro.

**Figure 5.** The “Tamino” motive. (a) The six-note motive with layer analysis; (b) Mozart, *Die Zauberflöte*, K. 620, Aria no. 3, Larghetto, “Dies Bildnis,” mm. 3–10; (c) Mozart, String Quartet in Eb major, K. 171, i, Adagio introduction, mm. 1–8; (d) Mozart, Oboe Quartet in F major, K. 370, i, Allegro, mm. 8–14.

**Table 3:** Occurrences of the Prototype *Tamino Motive Literal* in Mozart’s Complete Works

Work	Movement (key)	Tempo, meter	Individual Instances (local keys)
String Quartet in Eb major, K. 160 (159 <sup>a</sup> )	i (Eb major)	Allegro, C	mm. 24f., 26f. (Bb major) mm. 83f., 85f. (Eb major)
String Quartet in F major, K. 168	i, (F major)	Allegro, C	mm. 33f. (C major) mm. 100f. (F major)
String Quartet in Eb major, K. 171	i (Eb major)	Adagio, C (followed by Allegro assai, 3/4)	mm. 1f. (Eb major) mm. 143f. (Eb major)
Serenade in D major, K. 203 (189 <sup>b</sup> )	vi (G major)	Andante, 2/4	mm. 2f., 46f. (G major)
Divertimento in D major, K. 205 (173 <sup>a</sup> , 167A)	iii (A major)	Adagio, C	mm. 2f. (A major)
<i>Idomeneo</i> , K. 366	Aria no. 11 (Ilia) (Eb major)	Andante ma sostenuto, 2/4	mm. 3f., 17f., 60f. (Eb major)
Symphony in G minor, K. 550	ii (Eb major)	Andante, 6/8	mm. 5f., 13f., 78f. (Eb major)
<i>Die Zauberflöte</i> , K. 620	Aria no. 3 (Tamino) (Eb major)	Larghetto, 2/4	mm. 7f. (Eb major)

Considered as a melodic prototype, the “Tamino” motive may give rise to diverse variants derived by either adding ornamentation to the bare, generic six-note sequence or omitting and/or replacing individual pitches through other pitches. The wealth of possible variation is inexhaustible, but as we move farther away from the basic structure, it becomes less clear whether concrete instances still relate to the “Tamino” motive, or rather to more general melodic schemata of which the motive itself is an instantiation. Accordingly, we limit our survey of variants of the “Tamino” motive to instances fulfilling the two following criteria: (1) at least five of the six pitches making up the motive are present, logically also in their respective order; and (2) the respective pitches fall into two distinct phrases, with an underlying symmetry between them. A total of 31 occurrences in Mozart’s entire oeuvre—in addition to the eight literal ones listed in Table 3—correspond to these specifications.

A closer examination of this extended corpus reveals that some instances are more similar to the original motive than others. These instances, representing a near-literal level of resemblance, possess all six pitches of the original sequence, and, in addition, feature the two particularly salient diminished-interval leaps—the diminished fourth between tones 1 and 2 and the diminished fifth between tones 4 and 5—in their original, unmediated form. As an example of these near-literal instances, consider the first movement of the Oboe Quartet K. 370, mm. 8–10 (Figure 5d): here the motive is decorated solely through the two figures winding about tones 1 and 4. To handle the varying levels of similarity to the original motive, we define three prototypes—*Tamino motive literal*, *near-literal*, and *non-literal*—with all the instances of the more literal prototypes also subsumed under the less literal ones. For the sake of statistical evaluation, we regard all motive occurrences in a given movement as a single instance which is assigned the movement’s key (also where some of the individual occurrences are in divergent keys), provided that one motive occurrence at least is in the movement’s principal key.[20] Details regarding the instances of the three “Tamino” prototypes throughout Mozart’s works and their respective degrees of key-relatedness are provided in Table 4; see also Supplementary Table S3 for a comprehensive list of the instances of all three prototypes (a legend connecting the prototype names in Table 4 and the machine-readable labels in the supplementary table is provided in Supplementary Table S5).[5]

**Table 4:** Prototypes and instances of the “Tamino” motive in Mozart’s complete works

Prototype	Instances in 7 common keys	Preferred Key (instances in key)	<i>p</i> -value	FDR corrected
Tamino motive literal	8	E♭ major (5)	0.006*	0.033*
Tamino motive near-literal	13	E♭ major (7)	0.002*	0.019*
Tamino motive non-literal	34	F major (9)	0.201	0.394

To resume, our main working hypothesis in the present analysis is that by evaluating the key distribution among the instances of each of the 55 prototypes derived throughout the three domains of investigation, we will be able to statistically assess the key-relatedness of Mozart’s music as a whole. In the following section, we discuss the methodological challenges involved and the statistical tools devised to handle them.

## METHODS

We propose to test for statistically significant correlation between prototype occurrences and the choice of key at three different levels: the level of individual prototypes, the level of each of the three main domains of investigation, and the level of the overall evaluation. We assume phenomenological independence among prototypes belonging to different domains, notwithstanding the fact that in some cases prototype instances from different domains materialize in the same movement, sometimes even within the same stretch of music: consider, for instance, the two instances of minorization at the beginning of the Piano Concerto K. 503 (see Figure 4), which coincide with an occurrence of the topic-related prototype *sequenced antithetic opening theme*. By contrast, we assume interdependence among prototypes pertaining to the same domain of investigation. On the one hand, there are, for example, minorization instances that materialize side by side in the same movement in what appears to be an interdependent manner (consider, again, K. 503/i, mm. 6 and 17–26); on the other, as explained above, in all three investigation domains there are cases of multiple classification of given instances into several different prototypes, which creates interdependence among the prototypes. We address this latter issue in the following subsection.

## Multiple Classification

Not all instantiations of a general rule are “prototypical,” in the sense that they clearly exemplify the totality of aspects of the rule they supposedly pertain to (cf. Rosch, 1975; Deliège, 2001). Individual instantiations may express their relation to a subsuming rule in an only partial or vague way. Moreover, specific instances may be understood to exemplify several different rules. This constellation, in turn, requires some methodological adjustment, as will be clarified in the following discussion.

The Serenade *Eine kleine Nachtmusik* in G major, K. 525 opens with a loud, exuberant thematic presentation (see Figure 6a). As discussed above, this opening relates K. 525 to a group of themes that retain *forte* dynamics throughout, another instance—also in G major—being the opening theme of the Symphony K. 199 (Figure 6b). The latter theme represents an unproblematic instance of the *all-forte* prototype, as it remains in *forte* throughout the entire thematic presentation (mm. 1–19). The theme of *Eine kleine Nachtmusik*, by contrast, is not a prototypical instance of the rule, as at m. 11, several measures before attaining the thematic closure (which occurs at m. 18), the music drops to *piano*. Subsuming the opening theme of *Eine kleine Nachtmusik* under the prototype *all-forte* is sustained through bottom-up analysis, taking into account its being similar *enough* to other concrete instantiations of the rule in the corpus under investigation. However, at the same time this theme exemplifies characteristics of yet another prototype derived in our analysis—the prototype *cadential decrease* which involves a drop in dynamics shortly before the cadence. The opening theme of Mozart’s Bassoon Concerto K. 191 (Figure 6c) represents a characteristic example of this prototype. Note, however, that while the concerto’s theme drops to *piano* just preceding the cadence, the *piano* portion of the serenade’s opening theme (mm. 11–18) is considerably longer and more elaborate. Ultimately, the theme of *Eine kleine Nachtmusik* represents a case of fuzzy phenomenological boundaries: while it does not seem to fit neatly into any of the two prototypes it alludes to, considering it in the context of the entire corpus under analysis suggests a double classification into both prototypes to represent the most adequate solution. Incidentally, when classified into the prototype *all-forte*, the theme joins a statistically significant bulk of instances in G major; in conjunction with the prototype *cadential decrease*, on the other hand, it exhibits no key-specific association.

Allegro

(a)

Figure 6 consists of three musical excerpts, each in a grand staff (treble and bass clefs).  
 (a) *Serenade in G major, K. 525, Eine kleine Nachtmusik, i, Allegro, mm. 1–18*. The music is in 3/4 time. It features a strong dynamic *f* (forte) and includes trills (*tr*) in the upper voice. The bass line is a steady eighth-note accompaniment.  
 (b) *Symphony in G major, K. 199, i, Allegro, mm. 1–19*. The music is in 3/4 time. It features a strong dynamic *f* and includes trills (*tr*). The bass line is a steady eighth-note accompaniment.  
 (c) *Bassoon Concerto in Bb major, K. 191, i, Allegro, mm. 1–6*. The music is in 2/4 time. It features a strong dynamic *f* and includes trills (*tr*). The bass line is a steady eighth-note accompaniment.

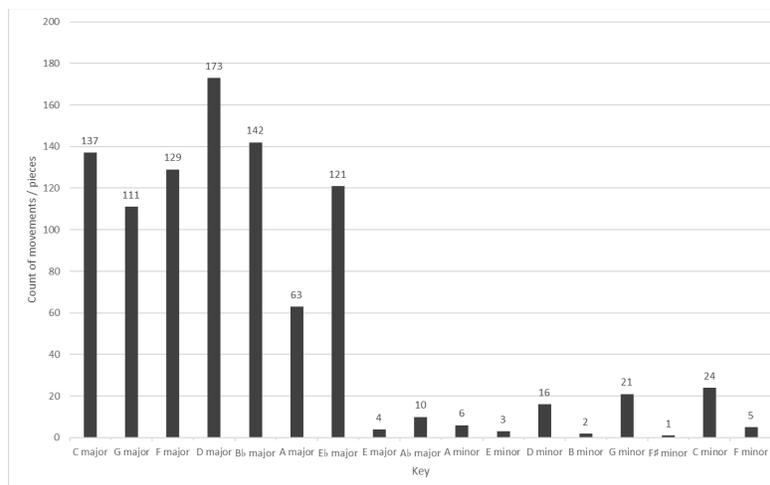
**Figure 6.** Mozart, (a) Serenade in G major, K. 525, *Eine kleine Nachtmusik*, i, Allegro, mm. 1–18; (b) Symphony in G major, K. 199, i, Allegro, mm. 1–19; (c) Bassoon Concerto in Bb major, K. 191, i, Allegro, mm. 1–6.

To accommodate the real-world, “fuzzy” behavior of many of the prototype instantiations under investigation, we embrace multiple classification as a central aspect of our method, with some instances subsumed under no less than four, or even five different prototypes (see Supplementary Tables 1, 2, and 3 for further details).[5] Our statistical method is adapted to sustain the resulting network of dependencies among prototypes.

## Statistical Method

The statistical method used to evaluate our analysis results combines traditional parametric approaches with non-parametric and simulation-based ones, according to need, as described below.

*Background key distributions.* As a preliminary step, we generate relevant reference key distributions for each of the investigation’s three main domains (for the data used to generate these three distributions, see Supplementary Table S4).[5] For the dynamic-rhetoric opening gestures, the background distribution is that of Mozart’s 134 orchestral works for orchestra/large ensembles, whereas for the minorization prototypes, we use the key distribution of Mozart’s 450 sonata-allegro movements. Instances of the “Tamino” motive were located across Mozart’s complete works; however, our data encompass information for Mozart’s instrumental music only. We consider the key distribution among Mozart’s 968 instrumental movements and standalone pieces shown in Figure 7 to embody an acceptable approximation of the key distribution across his complete works, including the vocal genres.



**Figure 7.** Key distribution among Mozart’s 968 instrumental movements and stand-alone pieces.

A telling characteristic of all three reference distributions is that Mozart’s output by and large focuses on the seven “simplest” major-mode keys, with none to three accidentals. Whereas these seven keys as a group span over 90% of all instrumental pieces (see Figure 7), the remaining “off-centered” major-mode keys and all minor-mode keys occur much less frequently. Notably, Mozart’s movements in minor amount to only about 8% of the total distribution. There are some indications (e.g., Brook, 1962; Brook & Heyman, 1979–86) that a similar preference for the same group of seven major-mode keys is also characteristic of the music of the second half of the eighteenth century in general.

For considerations of statistical power, we include in our evaluation only instances derived from movements in the seven most common major-mode keys, adjusting the various reference distributions accordingly. For similar reasons, prototypes with less than three instances are disregarded in the evaluation: among the disregarded prototypes are, for instance, prototypes of minorization at the development’s beginning that involve particularly rare subsequent modulation goals.

*Calculating p-values for correlation between prototypes’ employment and key choice.* Given a prototype and a reference distribution, under the null-hypothesis of no association between key and prototype occurrences, we may consider the movements containing prototype occurrences as a random sample from the reference distribution. Denote the counts for the seven keys in the reference distribution by  $n_1, n_2, \dots, n_7$ , with  $n_1 + n_2 + \dots + n_7 = n$  standing for the total number of movements considered; and the corresponding counts for the movements in which the prototype occurs by  $m_1, m_2, \dots, m_7$ , with  $m_1 + m_2 + \dots + m_7 = m$  representing the prototype’s total occurrences. Then, under the null-hypothesis, the occurrences in any specific key have a hypergeometric distribution:  $m_i \sim \text{HG}(n, n_i, m)$ ,  $i=1, \dots, 7$ , and an exact  $p$ -value under the null-hypothesis can be obtained applying Fisher’s exact test (Fisher, 1925).

Since the alternative hypothesis we wish to test is that only one of the seven available keys is associated with a given prototype, but we do not specify in advance which one, it would be inappropriate to take the lowest hypergeometric  $p$ -value among the seven keys as the prototype’s  $p$ -value. A naïve Bonferroni multiple comparison correction would multiply that smallest  $p$ -value by seven, given the seven common keys participating in the analysis. However, this correction may be significantly too conservative, since these  $p$ -values are dependent, and since the values  $n, n_i, m$ , may *a priori* preclude some keys from attaining low  $p$ -values.

Therefore, we proceed to calculate an individual prototype’s  $p$ -value using a simulation approach, whereby we estimate the null distribution of the lowest  $p$ -value among the seven hypergeometric  $p$ -values by repeatedly drawing samples of size  $m$  from the reference distribution and collecting the values assumed by the lowest hypergeometric  $p$ -value. The  $p$ -value for the real-data result is the percentage of simulations yielding a lower result than the real-data one (ties are counted as  $1/2$ ).

*Correction for multiple comparison using False Discovery Rate (FDR).* Given a  $p$ -value calculated as above, we seek to identify prototypes that are significantly associated with one specific key. Since a total of 47 prototypes participate in the evaluation, we must bear in mind the multiple comparison aspect: considering a large-enough set of prototypes, we are bound to find at least some that possess significant  $p$ -values and therefore appear to attest to a correlation between key choice and prototype occurrences, even if

none truly exists. Accordingly, we apply the FDR approach (Benjamini & Hochberg, 1995) to correct the  $p$ -values.

*Using simulation to test the composite null-hypothesis of no key-relatedness.* In addition to identifying individual prototypes that are associated with a specific key, we also test the composite null-hypothesis that no association exists between key choice and the employment of prototypes. Had the  $p$ -values for the individual prototypes been statistically independent, a straightforward approach would have involved applying Fisher's meta-analysis (Fisher, 1925). However, this is not the case: owing to our multiple classification of certain individual instances into several different prototypes, no statistical independence among the evaluated prototypes can be assumed. We accordingly apply a simulation approach as explained below.

Assume we have a fixed reference distribution as above, and a total of  $k$  non-independent prototypes relating to this reference distribution. We begin by calculating the product of the  $p$ -values for the set of prototypes as in Fisher's meta-analysis (typically, its logarithm is taken, yielding the sum of the  $\log p$ -values). Given that each one of the elements in our relevant reference distribution has a set of zero or more prototypes associated with it, our simulation consists of randomly permuting the keys among all pieces, thus associating a key chosen at random with each piece, while maintaining the set of prototypes that occur in each piece, and consequently also their dependence structure. For each of these permutations, we generate a product statistic by calculating  $p$ -values for all individual prototypes and multiplying them. The simulation-based  $p$ -value for the composite null-hypothesis is the percentage of permutations that yield a value for the product statistic that is lower than that derived from the actual distribution of prototypes in Mozart's music. Since this percentage in itself is an estimate of the true  $p$ -value, with its accuracy depending on the number of simulations performed, we further calculate a one-sided 95% confidence interval for the "actual"  $p$ -value, using a Poisson approximation (Clopper & Pearson, 1934). We then take the upper bound of the confidence interval as a conservative estimate of the  $p$ -value.

In order to generate the overall combined  $p$ -value for the entire analysis, we assume that the three prototype categories corresponding to the three main domains of investigation—while featuring non-independent prototypes as described above—are independent of one another. Hence, after applying a simulation approach to calculate a composite null  $p$ -value for each category, we use Fisher's meta-analysis calculation to combine the three values into a single  $p$ -value for the global null standing for the overall result of our analysis.

## RESULTS

Tables 1, 2, and 4 above show the total 55 prototypes gleaned from the three main domains of investigation alongside the number of individual instances for each prototype. The statistical evaluation spans only the 47 prototypes for which there are at least three instances per prototype, taking into account only instances in the seven common major-mode keys (see Statistical Method above). The  $p$ -value and the FDR columns represent the statistical significance of a prototype's attachment to one of the seven common keys before and after correction for multiple comparisons, respectively. The "preferred key" column specifies the statistically dominating key for each prototype and the number of individual prototype instances in this key. Note, however, that a prototype's attachment to the designated preferred key is only statistically significant in conjunction with a significant  $p$ -value.

Ten of the 47 prototypes evaluated possess significant  $p$ -values (at level  $p < .05$ ) after correction for multiple comparisons, and are considered to represent veritable key-related idioms. These are marked in Tables 1, 2, and 4 through asterisks in the  $p$ -value and FDR columns. An additional six prototypes have significant  $p$ -values before correction, and are accordingly marked through asterisks in the  $p$ -value column only. Strictly speaking, a statistically significant correlation between a prototype and a key can be inferred only for the ten prototypes that retain significant  $p$ -values after correction. However, since also the six prototypes that display a significant  $p$ -value before correction contribute toward the combined overall  $p$ -value, we regard them as *potentially* key-related and, accordingly, as relevant to our research endeavor.

The meta-analysis  $p$ -values derived from each of the three main domains of investigation are:

- Dynamic-rhetoric opening gestures (13 prototypes evaluated, based on  $10^6$  simulations):  $p = 1.2 \cdot 10^{-3}$
- Minorization (31 prototypes evaluated, based on  $3 \cdot 10^6$  simulations):  $p = 1.3 \cdot 10^{-6}$
- Occurrences of the "Tamino" motive (3 prototypes, based on  $10^6$  simulations):  $p = 4.2 \cdot 10^{-3}$

The combined meta-analysis  $p$ -value for the entire evaluation is  $p = 2.3 \cdot 10^{-9}$ .

In the first domain of investigation—dynamic-rhetoric opening gestures in Mozart’s works for orchestra/large ensembles—we define 14 prototypes, 13 of which take part in the statistical evaluation. Three prototypes maintain a significant  $p$ -value after correction and may accordingly be considered to represent veritable key-related idioms. One of these is the *all-forte* prototype associated with G major at  $p < .02$  (see Figures 6a and 6b). Notably, G major is one of the less frequent keys among Mozart’s works for orchestra/large ensembles; the fact that eight of the thirteen works in this key commence with *all-forte* themes appeals even intuitively as an impressive bulk, all the more so when taking into consideration that this prototype occurs in only six works in D major, otherwise by far the most common key among Mozart’s orchestral works (37 works—over a fourth of the corpus under investigation—are in D major). Another statistically significant key-related idiom in this category is that of asymmetrical antithetic themes, associated at  $p = .023$  (after correction) with Eb major. Remarkably, the nine themes in Eb major subsumed under this prototype additionally share with one another an intricate network of common structural features. For example, the broken triadic figure in unison texture used to launch Mozart’s First Symphony, K. 16 (see Figure 3b) is also found (with some modifications) at the beginning of the Piano Concerto K. 271 and some other themes of this Eb major group. In a similar vein, the opening themes of the Wind Serenade K. 375 and the Piano Concerto K. 482 incorporate a chain of suspensions identical with the one found in K. 16/i, mm. 4–11. Finally, the prototype *thematic repetition in reverse dynamics* is associated with A major at  $p = .043$ , with three symphonies in this key as well as the Clarinet Concerto sharing this dynamic-rhetoric strategy (notably, A major is the least frequent key among Mozart’s seven common keys; see Figure 7 above).

The next domain of investigation, minorization in Mozart’s sonata-allegro movements, yields the largest number of prototypes participating in the evaluation (31—there are an additional seven minorization prototypes with less than three instances per prototype which do not participate in the evaluation). Each of the three formal locations investigated—primary theme, secondary theme, and the development’s beginning—contributes 1–2 statistically significant key-related idioms; we were able to locate an additional six minorization prototypes that are only potentially key-related (significant  $p$ -values before correction).

In the primary-theme zone, *minorization of the tonic featuring an authentic cadence* is associated with C-major at a statistically significant level—with five of the total seven prototype instances occurring in this key. One of these instances is the minor-mode passage in mm. 17–25 of the first movement of the Piano Concerto K. 503 (see Figure 4). On the other hand, minor-mode digressions culminating in a *half cadence* are only potentially associated with the key of D major (a typical example being mm. 19–22 of the overture to the opera *Idomeneo*). Among the prototypes of minorization of the subdominant in the primary-theme zone, the use of the half-diminished degree  $ii^7_{sb}$  is exclusive to movements in C major, with four instances in this key ( $p < .02$  after correction), a typical example occurring in the first movement of the Piano Concerto K. 503, m. 6 (see Figure 4). Note that such exclusive associations between a given prototype and its idiomatic key are very rare across our entire analysis. A further characteristic of the single-chord minorization instance in K. 503/i, m. 6 is the introduction of the lowered sixth scale degree through a descending chromatic step from the natural sixth degree—this chromatic progression occurs in another five movements in C major (as well as five movements in other keys), making the subsuming prototype potentially attached to C major at  $p < .02$  before correction. Finally, minorization in the primary-theme zone using the degrees  $bII/bVI$  (two closely related major triads expressing a local digression to the parallel minor) is associated with A major at  $p < .02$  before correction.

In the secondary-theme zone, the only statistically significant idiom is the *type 3 minor-mode echo* prototype, which is strongly associated with C major. Minor-mode echoes of type 3—referring to the minorization of interim elements across distance—typically involve two interrelated adjacent phrases (e.g., a period’s antecedent and consequent phrases), the second of which transfers some interim details of the first to the minor mode, while leaving the remaining elements in major. Figure 8 shows a particularly intricate example spanning mm. 170–187 of K. 503/i (incidentally, this concerto movement accommodates the largest number of individual digressions to the parallel minor found in any single movement of the corpus under analysis: 13). The theme shown in Figure 8, structured as a double period, employs type 3 minor-mode echoes at several different levels. First, each of the “small antecedents” (mm. 170–173 and mm. 178–181) contains a subdominant detail subsequently transferred to the minor mode at the corresponding position of the respective “small consequent” (at mm. 175 and 183, respectively). Additionally, the second of these “small periods” entails toward its end (m. 185) a type 3 minor-mode echo (this time involving a minorization of the tonic degree) pointing back to the cadential progression that concludes the first “small period” (at m. 176). Notably, since this minor-mode detail is additionally flanked on both sides by its major-mode counterparts,

it additionally constitutes an instance of both the *type 2 minor echo* and the *reverse minor-mode echo* prototypes (see definitions above).

The figure displays a musical score for Mozart's Piano Concerto in C major, K. 503, i, Allegro maestoso, mm. 170–187. The score is divided into four systems, each with annotations for musical structure and harmonic analysis.

- System 1 (mm. 170–175):** Piano Solo and Orchestra (Str.). Annotations include "small period" 1: antecedent and consequent, and "Type 3 minor-mode echo".
- System 2 (mm. 176–179):** Piano Solo and woodwinds (Ob., Bsn., Bassi). Annotations include "small period" 2: antecedent and "cadential progression".
- System 3 (mm. 180–183):** Piano Solo and woodwinds (Fl., Ob., Ve., Bassi). Annotations include "small period" 2: consequent and "Type 3 minor-mode echo".
- System 4 (mm. 184–187):** Piano Solo and woodwinds (Bsn., Ob., Ww., Bassi). Annotations include "Type 2 minor-mode echo", "reverse minor-mode echo", and "Type 3 minor-mode echo".

**Figure 8.** Mozart, Piano Concerto in C major, K. 503, i, Allegro maestoso, mm. 170–187.

Minor-mode echoes of type 1 are particularly common among secondary themes—with 42 instances in the corpus under investigation. Although the corresponding prototype’s association with the preferred key (D major in this case) is only potentially significant ( $p = .02$  before correction), it nonetheless stands out with the largest number of instances in the preferred key in comparison with all other prototypes included in our investigation, totaling 18 instances in D-major movements. A typical example of this procedure is the lyrical secondary theme of the “Prague” Symphony’s first movement (mm. 97–112, 244–259), structured as a parallel period with the consequent standing entirely in the minor mode.

Two statistically significant key-related idioms are found among the instances of minorization at the beginning of the development section, both involving minorization of the dominant key with a subsequent modulation to a comparatively rare tonal goal: the major key of the second degree (*II*), and the major key of the lowered seventh degree (*bVII*). These idioms are associated with the keys F major and E $\flat$  major, respectively, representing rare examples of prototypes whose instances occur exclusively in the idiomatic key. Regarding the second of these prototypes, note that modulating to the key of the lowered seventh degree in movements in the idiomatic key E $\flat$  major attains the rather off-centered local key of D $\flat$  major; given that none of Mozart's movements or standalone pieces stands in this rare key, this key-related idiom appears all the more remarkable. In addition, launching the development section with a *literal minor-mode restatement of the primary theme* is potentially related to C major ( $p < .04$  before correction), with six out of the twelve prototype instances in this key, typical examples being the first movement of the Piano Sonata in C major, K. 309 and the finale of the "Dissonance" Quartet, K. 465. Finally, the *type 3 minor-mode echo at development's beginning* prototype shows a potential attachment to the key of B $\flat$  major ( $p < .05$  before correction).

Regarding the "Tamino" motive, the eight *literal* motive instances (see Table 3 above) show a clear preference for E $\flat$  major, with five of them occurring in movements in this key ( $p = .033$  after correction). Revealingly, the *near-literal* prototype, subsuming—in addition to the eight literal instances—another five instances slightly deviating from the literal form, displays an even stronger association with the same key ( $p < .02$ ).

## DISCUSSION

A meta-analysis spanning all prototypes derived throughout our investigation yields a highly significant combined value ( $p = 2.3 \cdot 10^{-9}$ ), serving to reject the composite null-hypothesis that no correlation exists in Mozart's works between structural features, treated in our investigation through prototype definitions, and the choice of absolute keys. This overall result indicates that the individual key-related idioms identified in our analysis (also including the less pronounced *potentially* key-related prototypes with significant  $p$ -values before correction) are not merely anecdotal, but rather indicative of a systematic pattern in Mozart's creative process. At the same time, these results raise a number of additional questions regarding some possible implications of our analysis.

One central question is that of assessing the overall significance of key-related structure in Mozart's music. At one level, one may ask how many of Mozart's compositions contain key-related idioms; at another level, one may seek to assess their role in a given composition in terms of both the percentage a piece's length governed by them and the degree of structural and perceptual salience of the phenomena involved.

Table 5 offers an overview of Mozart's instrumental pieces featuring key-related idioms as gleaned from our investigation. The most extensive key distribution employed in our analysis—encompassing Mozart's 968 instrumental movements and standalone pieces—is shown as reference in the second column from the left (see also Statistical Method and Figure 7 above). The total 55 prototypes defined throughout the three domains of investigation (also including several prototypes that do not participate in the statistical evaluation) subsume instances from a total of 291 movements, whereby a single movement may contain instances of several different prototypes. These are shown in the next column. Among these 291 movements, 83 (about 29%) feature prototypes that are at least potentially associated with a specific key, of which 50 movements contain veritable key-related idioms (with significant  $p$ -values after FDR correction), as shown in the rightmost column (note that the numbers of movements containing veritable key-related idioms appear in parentheses and are marked by asterisks).

**Table 5.** Mozart's instrumental movements, movements with prototype instances and movements with key-related idioms

Key	Instrumental movements	Movements with prototype instances	Movements with potentially significant and statistically significant (*) key-related idioms
C major	137	54	21 (15*)
G major	111	27	8 (8*)
F major	129	36	4 (4*)
D major	173	72	21 (0*)

Bb major	142	54	4 (0*)
A major	63	20	6 (4*)
Eb major	121	33	19 (19*)
Other keys	92	13	-
Total	968	291	83 (50*)

Notably, the most widespread tonality in the repertoire under investigation—D major—is associated with no veritable key-related idioms, and with only two potentially significant idioms (both representing minorization prototypes), with instances stemming from a total of 21 movements in this key. Note that owing to the prevalence of D major in the reference distributions employed in our analysis, a prototype must materialize in a considerable number of movements in this key in order for a statistically significant association to arise. The second most widespread key among Mozart’s instrumental movements—Bb major—is associated with a single, only potentially key-related prototype, with instances occurring in a total of four movements. In the keys F major and G major, four and eight movements, respectively, are found to feature instances of key-related idioms, all of which possess statistically significant *p*-values after correction. Among the 21 movements in C major listed in the rightmost column, 15 movements contain instances of statistically significant idioms, whereas the remaining six movements feature instances of only potentially significant ones. Probably most interesting in this overview is the key of Eb major with 19 movements featuring instances of statistically significant key-related idioms. In conjunction, Eb major is the only key across the entire analysis found to be associated with idioms derived from all three domains of investigation: opening dynamic-rhetoric gestures, minorization, and the “Tamino” motive.

Although the overall number of movements that feature significant and potentially significant key-related idioms—83 movements in total—may appear rather small in relation to Mozart’s sizable output, it is important to bear in mind that our prototype definitions cover only a relatively small portion of Mozart’s instrumental music to begin with—291 movements in total (as shown in the table’s middle column). Arguably, it is in relation to this smaller body of works that our key-related findings should be assessed. Ultimately, while on the basis of our present analysis key-related idioms cannot be claimed to permeate Mozart’s oeuvre, the number of movements exhibiting at least some level of key-relatedness gleaned from an investigation of just three musical phenomena seems encouraging.

Turning now to assess the role of key-related idioms in a given composition, one may distinguish between two related questions: the scope of key-related elements in relation to the piece’s length and their structural and perceptual salience. In terms of scope, individual key-related instances range from a single sonority (as in the case of the one-chord minorization instance in K. 503/i, m. 6, see Figure 4) to an extensive thematic presentation (as, for instance, in the case of the opening theme of the Symphony K. 16, i, mm. 1–22, see Figure 3b). On the basis of our analysis, it seems safe to assume that as a rule, no more than a certain proportion—say, 10%—of a given movement’s duration can be said to be governed by key-related idioms. On the other hand, there seems to be no upper limit to an idiom’s potential degree of structural and perceptual salience. The three key-related idioms gleaned from our first domain of investigation—dynamic-rhetoric opening gestures—enjoy maximal salience due to their position at an orchestral work’s beginning. Seven of the statistically significant and potentially significant minorization idioms gleaned from the second domain of investigation pertain to primary and secondary themes (see Table 2): although being embedded in a thematic presentation arguably grants such minorization instances a certain degree of salience, some of them represent rather brief, inconspicuous events. Finally, whereas most of the instances of the “Tamino” motive are exposed melodically and easily perceptible, a few of them (such as, for instance, the one from the String Quartet in Eb major, K. 160, i, mm. 24ff., 83ff.) are concealed at a phrase’s interim position and hence less salient.

Another aspect worth exploring with regard to Mozart’s employment of key-related structure is that of how individual idioms, and the composer’s overall proclivity to use them, developed over time. Notably, different idioms have very different histories: for instance, the association between the “Tamino” motive and the key of Eb major has a lifespan of almost twenty years dating back to the first occurrence in the String Quartet K. 160 of 1772/73 and extending to the latest one in *Die Zauberflöte* of 1791; by contrast, the C-major-related idiom *Type 3 minor-mode echo in secondary-theme zone* has a much shorter history, spanning about six of Mozart’s Viennese years, with occurrences ranging from the third movement of the Piano

Concerto in C major, K. 415 to the finale of the “Jupiter” Symphony. Some preliminary findings, not reported here, suggest that Mozart’s overall employment of key-related idioms intensified with time. Further investigation into Mozart’s key-related structure will be needed in order to model reliably the chronological aspect of his key-specific composition. Ultimately, we conjecture that individual key-related idioms in Mozart’s music may potentially congeal into more comprehensive key-related styles, sufficiently well distinguishable from one another on the basis of recurrent key-specific structures, but then again, more extensive examination will be needed in order to test this hypothesis.

An important cluster of questions concerns the possible role of key-related structure in other composers besides Mozart. Theoretically, any tonal composer may develop his or her set of key-related idioms, which may differ substantially from those of other composers. On the other hand, it is also possible for the members of a composers’ community to share common key-related idioms: this could either be the result of composers learning from one another and imitating one another (cultural influence), or otherwise there could be some more general, “objective” reasons for a particular structural token to associate itself with a specific key. In the following, we begin by contemplating some possibilities of linking the key-related structures identified in our research with physical characteristics of individual keys, especially such characteristics that are known to have played a role in the sonic reality of Mozart’s time. We then proceed to discuss additional aspects of culturally conditioned key-related composition traditions and conventions.

In the extensive literature on key characteristics, differentiation among identically structured keys is often linked to particular acoustic features of specific keys. One such feature concerns nuance of interval sizes in non-equal tunings. Demonstrably, in Mozart’s Salzburg and Vienna non-equal tunings were still largely in use (Stradner, 1991, p. 110), meaning that, while all keys (or, at least, those with a small number of accidentals) were well in tune, each had a slightly different interval structure. Let us examine one example of how non-equal tuning might affect key-related structure.

Johann Philipp Kirnberger (1771–79, 2: p. 71f.) attributes to the key of E $\flat$  major “terrifying power” due to its tuning scheme which entails particularly narrow semitones. Admittedly, against the backdrop of eighteenth-century compositions in E $\flat$  major Kirnberger’s characterization seems one-sided: while it agrees with the recurrent employment of this key to symbolize death and the underworld (as observed, for instance, by Webster, 1998), it obviously fails to do justice, for instance, to the key’s frequent association with amorous arias—such as Tamino’s “portrait” aria quoted in Figure 5b (consider Webster’s characterization of *aria d’affetto*, 1991, p. 107). However, we proceed from the assumption that the historical tuning scheme of E $\flat$  major may have given rise to certain key-related compositional strategies also regardless of any specific semantic content. In a study on chromatic features of works in E $\flat$  major of the Classical repertoire, Anson-Cartwright (2000) provides some substantial evidence of what he identifies as a strikingly extensive use of chromaticism in works in this key by Haydn, Mozart, and Beethoven—a fact that he relates to the key’s particular tuning scheme. Notably, the six-note motive shown in our study to be associated with E $\flat$  major at a statistically significant level features two chromatic pitches (nos. 2 and 5 of the sequence; see Figure 5a). While this links the motive with a chromatically imbued compositional profile of E $\flat$  major, possibly going back to the key’s sonic profile, the association of E $\flat$  major with chromaticism appears to transcend the boundaries of Mozart’s personal style, representing an intersubjective, “communal” characteristic of composing in this key in the late eighteenth and early nineteenth century.[21]

Another type of sonority-related differentiation among the keys has to do with the way specific keys sound on specific instruments. For instance, it is tempting to link the strategy of maintaining a constant *forte* level throughout the primary theme presentation—which we show to be idiomatic to Mozart’s opening orchestral themes in G major (see discussion of the *all-forte* prototype above)—with the particularly resonant sonic profile of this key on stringed instruments due to the many co-resonating open strings. Indeed, as indicated by our analysis, Mozart uses this strategy to launch six out of his seven symphonies in G major, as well as another two works in this key, in all of which the strings section plays a major role. Now, assuming an acoustically conditioned association between this dynamic-rhetoric profile and the key of G major, one would expect it to pertain to a wider range of composers. However, Haydn’s orchestral music, for one thing, shows no trace of this association: only two of his twelve symphonies in G major commence with an *all-forte* theme.[22]

Ultimately, it is important to observe that key-related compositional traditions shared by the members of a cultural community need not necessarily go back to any key-specific acoustic properties—at least, the contribution of a key’s sonic profile to the emergence of such traditions may be marginal or even equivocal. A case in point is the Viennese trumpet overture/sinfonia, which—as a subgenre of the *galant* and

Classical symphony/overture (Brown, 1996, p. 13)—attached itself to the key of C major, notwithstanding a preference for D major among some of its Italian counterparts. To be sure, trumpets in D were available also in Vienna, making the Viennese tradition's near-exclusive focus on C major a cultural convention rather than an orchestrational necessity. Key-specific subgenres like the Viennese trumpeting symphony represent potential sources for key-related idioms, because the subgenre itself comes ready with a set of structural attributes, such as typical rhythmic and melodic figures and formal procedures (cf. Brown, 1996, 2003). Intriguingly, Mozart's key-related idioms do not seem to be genre-oriented: at least, the instances of the "Tamino" motive and some of the minorization idioms gleaned from our investigation are derived from a wide variety of instrumental and vocal genres, and even our analysis of Mozart's opening orchestral themes reveals remarkable parallels between themes derived from, say, symphonies, wind serenades, and piano concertos. Here, again, further research will be needed in order to identify and assess key-related conventions that Mozart possibly had in common with other composers, and their possible anchoring in broader composition traditions.

To conclude, we address the possibility that the phenomenon of key-related idioms as defined and explored in the present study may prove to be largely restricted to Mozart's music. In such a case, the reasons for the emergence of key-relatedness in his works must be sought in connection with aspects of his personal creative process. Arguably, due to Mozart's well-documented superb sense of absolute pitch, he would store in his memory musical elements (either his own, or assimilated from works by others) at their original pitch level, that is, also in connection with their original key. Given that Mozart's musical memory was key-oriented, it seems plausible to assume that in the course of composing a new piece in a given key, elements already stored in his memory in connection with that key would enjoy a cognitive advantage (although the composer was of course perfectly free to override such preferences). This explanation strategy links the emergence of key-related idioms in Mozart's music with both the composer's absolute pitch and his phenomenal musical memory.[23]

Assuming, for the argument's sake, that Mozart's key-relatedness represents an idiosyncratic trait of his personal style, we point to a possible connection between our findings and an aspect of the composer's use of the keys that has intrigued generations of scholars and enthusiasts: namely, Mozart's surprisingly narrow range of tonalities, considered by some commentators to represent a token of conservatism or pragmatism on his part (Einstein & Mendel, 1941; Zaslav, 1989). In comparison, Haydn, Mozart's senior by a quarter of a century, is known for his daring experimentation with off-centered keys, such as B major and C-sharp minor, keys in which Mozart practically never composed. Assuming—as suggested by our results—that in Mozart's mental archive common keys such as C major, or Eb major were associated with a particularly rich choice of idiomatic elements, we argue that this may have represented for him a particular incentive to compose in these keys. Once a key became a favorite (and, notably, the seven common keys are also the simplest ones in terms of key signature), writing in it would inspire a positive feedback mechanism. Conversely, rare keys, such as, say, B minor, would hardly ever come to develop a network of associated idioms, and consequently bring little zest into Mozart's creative process. On the other hand, when—by way of exception—composing in such rare keys, Mozart would have to overcome his natural proclivity to concentrate on a small range of keys, thus rendering his choice of an uncommon key all the more outstanding and expressive (consider, for instance, the poignant *Adagio* for Piano in B minor, K. 540).

A final cluster of questions concerns possible implications of our present investigation into Mozart's structure-bound key-relatedness for a re-assessment of the traditional concept of key characteristics. While the notion of a key's character evokes the image of an overarching, essentially consistent mode of expression linked with a given key, even a quick glance at the various characterizations offered in historical sources for particular keys would suffice to demonstrate the essential disparity and inconsistency among the attributes assigned. While Johann Philipp Kirnberger (1771–79, 2: pp. 71f.) refers to Eb major, for instance, as a key of "terrifying power," Johann Mattheson changes his mind from associating it with "great pathos," "serious" and "plaintive things" (1713, p. 249) to calling it "beautiful," "majestic," and "honest" (1719, p. 44). On a more general note, the historical literature on key characteristics bears witness to writers' conflict between a struggle for a clear-cut, consistent characterization and the heterogeneous musical reality they set out to describe. Can our investigation of key-related structure in Mozart also shed some light on questions of key-related semantics in his music?

To judge by the outcome of our analysis, the idioms pertaining to a given key do not seem to fall compellingly under any unified semantic/expressive category. This is demonstrated by the evident discrepancy among the three idioms we deem associated with Eb major at a statistically significant level (see

Tables 1, 2, and 4). While there might be an underlying structural and expressive correspondence between the chromaticism of the “Tamino” motive and Mozart’s practice of modulating to the rare key of D $\flat$  major in development sections of E $\flat$ -major sonata movements, this somber, chromatic hue associated with the key doesn’t seem to agree with its also being the idiomatic key of Mozart’s asymmetrical-antithetic opening orchestral themes—themes which are mostly diatonic and luminous. The latter idiom’s occurrences—as, for instance, in the first movements of the Symphony K. 16, the Sinfonia Concertante for Violin and Viola K. 364, and the Piano Concerto K. 482—bring to mind the “majestic” epithet assigned to E $\flat$  major by Mattheson, but definitely not the “terrifying” expression Kirnberger associated with it.

We finally propose that the concept of key-related structure may offer an important correction to the historical discourse on key characteristics. Instead of seeking to explain a piece’s semantics against the backdrop of an overarching, allegedly coherent key character, we suggest that it is rather through concrete structural attributes associated with a given key—to which we refer as “key-related idioms”—and through their particular interaction in a given work, that key-related semantics arise. Thus, the presence of several different key-related idioms in the same piece may also give rise to compound musical semantics. The overall expression of the first movement of the Piano Concerto in E $\flat$  major, K. 482, for example, may be construed to result from its featuring both the “majestic” antithetic opening theme and the “dark” modulation to D $\flat$  major at the development’s beginning—this compound character, possibly unique to this composition, resists being reduced to any textbook list of key characteristics.

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## AUTHOR CONTRIBUTIONS

UR and SR conceptualized the investigation and wrote the article together. UR annotated the musical corpora and supplied the music-theoretical inferences and the discussion. SR conceptualized and performed the statistical analysis and wrote the Statistical Method section.

## NOTES

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[2] Our employment of the term “prototype” in this context requires some explanation, as the customary use in categorization research is in the sense of the “clearest cases, best examples” of a given category (Rosch, 1975, p. 193)—that is, to denote particularly “prototypical” instantiations rather than abstract categories. More recently defined as “a set of prominent properties showing in itself an average of the main dimensions of a broader set of items” (Deliège, 2001, p. 371), the term's meaning seems to have shifted from that of a prototypical instantiation to refer to a more general set of rules subsuming such prototypical instantiations. This appears to be the meaning assigned to prototypes also in topical research into musical schemata (as, e.g., in Gjerdingen, 2007). In this sense, the term is closely related to the prevalent use of “*Modelle*” or “*Satzmodelle*” in German music theory (see Schwab-Felisch, 2007). We employ the term to refer to an essentially narrowly defined cluster of features, resulting from the combination of several typological specifications.

[3] The Clarinet Concerto K. 622 was originally conceived for the now obsolete basset horn in G, and Mozart's sketch in G major—a whole tone below the concerto's final pitch—has come down to us (in fact, he appears to have switched to A major in the course of notating this fragment). The existence of this earlier version in G major naturally casts some doubt on the opening melodic gesture's being a token of Mozart's A-major style.

[4] In the case of multi-movement overtures (such as the overture to *Mitridate*, K. 87) we only regard the opening sonata-allegro section in our analysis. We omit from our survey cycle-opening movements that do not correspond to the sonata-allegro type (e.g., K.186/i). On the other hand, the second movement, Allegro di molto, of the Divertimento K. 137 is included, as it fulfils a “first-allegro” function in this cycle, following an opening andante movement that may be construed—with some license—as a slow introduction.

[5] For Supplementary Tables S1–S5, please refer to the article's online supplementary materials at <http://hdl.handle.net/1811/102575>.

[6] For the origin of the “curtain” concept and a typology of curtain figures in works of the Classical and pre-Classical era, see Riemann 1903, p. 131; Gleim 1984, pp. 19ff., 74ff.

[7] Minorization instances occurring in primary-theme based codas are ignored in this analysis. In sonata-rondos we construe the first and the third refrain as analogous to the primary theme's expositional and recapitulatory occurrences, respectively. The second refrain is construed as corresponding to the development section's beginning.

[8] Stemming from different positions across the same movement, passages subsumed under a single minorization instance typically share the same musical material, including an identical use of minorization. However, there are several notable exceptions. For instance, in the first movement of the Piano Concerto in C major, K. 503, the extensive passage in the tonic minor in mm. 17–26 of the orchestral introduction concludes with an authentic cadence (see Figure 4), whereas the analogous passages in the exposition and

recapitulation (mm. 128–146 and 306–324, respectively) conclude with a half cadence. We classify the conflated minorization instance which subsumes all three occurrences under both corresponding prototypes, although none of the actual occurrences feature both an authentic and a half cadence.

[9] In case a digression to the tonic minor is introduced in the course of the primary-theme restatement in the recapitulation but there is no analogous shift to minor in the exposition, we construe the minor-mode digression as a means of varying the recapitulatory transition section and not as part of the recapitulation's primary-theme zone proper. Accordingly, cases such as the extensive minorization passage in the first movement of the Concerto for Two Pianos in Eb major, K. 365, mm. 208ff. are not included in our corpus of primary-theme related minorization instances.

[10] Regarding problems of distinguishing secondary-theme elements from elements of the transition on the one hand and the closing group on the other, consider, for example, Hepokoski & Darcy, 2006, pp. 159ff., 170ff.

[11] Unlike the minorization prototypes defined for the primary-theme zone, which cover all instances occurring in this zone and only them, we refrain—for reasons explained above—from delineating the secondary-theme zone in the movements under analysis. Instead, we define our secondary-theme related minorization prototypes to subsume instances that (a) occur in the secondary-key area, and (b) correspond to a limited choice of minorization procedures. As a result, minorization instances stemming from veritable secondary-theme modules but not falling under our choice of prototypes are excluded from this analysis—consider, e.g., the highly expressive minor-mode digression in the opening movement of the Piano Concerto in G major, K. 453, mm. 126–135, 277–286. On the other hand, we occasionally take into account minorization instances that demonstrably do not stem from the secondary theme proper, provided that they occur in the secondary-key area and correspond to our choice of minorization prototypes—consider, e.g., the minor-mode echoes in the first movement of the String Quartet in Eb major, K. 428, mm. 56–64, 152–160, which represent post-secondary-theme codetta elements, or the brief echoes in the first movement of the Piano Concerto in A major, K. 488, mm. 95f. and 225f., which stem from the transition's post-modulation section. In several cases, such as the opening movements of the Piano Concertos K. 467, K. 482 and K. 595 and the overture to *Idomeneo*, Mozart introduces extensive minor-mode themes which, notably, occur in the exposition only and are not recapitulated (note that drawing on Cone's "sonata principle," 1968, secondary-theme modules are expected to occur in both the exposition and the recapitulation). Although these minor-mode themes arguably belong to the transition section, they are nevertheless subsumed under the *minor-mode theme* prototype and included in our analysis.

[12] Minor-mode echoes of type 1 occasionally represent heavily altered versions of the original, making identification of the correspondence between major and minor elements particularly challenging—consider, for example, the finale of the "*Linz*" Symphony K. 425, mm. 93–116, 328–351.

[13] Occasionally, passages involving a minor-mode echo may be construed—due to ambiguous borders between syntactical units—both as launching a new syntactical unit and as continuing an ongoing one. In such cases, we opt for a double classification under both the *type 1* and the *type 2 minor-mode echo* prototypes—consider, e.g., the enchanting minor-mode echo in the first movement of the "*Paris*" Symphony, K. 297, mm. 66–73, 220–227, which can be heard both as a new thematic element and as a continuation of the preceding thematic module beginning at m. 52/m. 206.

[14] In major-mode movements, modulating to the minor-mode key of the second degree (ii) at the development's beginning—which may (but need not) be preceded by a minorization of the dominant key (v)—is discussed in eighteenth-century composition manuals as a standard modulation goal at the beginning of the movement's second part, i.e., following the double bar. This strategy is dubbed "*fonte*" in Riepel, 1752–86, 2: p. 44 (cf. also Gjerdingen, 2007, pp. 197–218).

[15] A typical instance of the minorization prototype *targeting the minor subdominant at development's beginning* occurs in the first movement of the "Haffner" Symphony, K. 385, mm. 95–104, whereby the dominant key A major, which has been established at the exposition's end, gradually mutates into the

dominant of D minor by using the pitches B $\flat$ , G, and F natural, without, however, actually attaining the targeted minor-mode key. The D minor *fortissimo* outburst in the development of the first movement of the Sonata for Two Pianos in D major, K. 448, mm. 90ff. is a representative example of the other prototype, *modulation from V to i*, under which we subsume instances in which the modulation to the tonic minor is actually accomplished, coinciding with a sense of a new section's beginning. In a small number of cases (such as the finale of the Piano Sonata in D major, K. 576, mm. 82ff.), the tonic minor (i) is attained following a reinstatement of the tonic major (I) at the development's beginning—while in such cases there is no direct contact between the secondary-key tonic (V) and the minorization key (i), this tonal progression seems nonetheless similar enough to the one described above to justify classification into the same prototype, *modulation from V to i*.

[16] A rare example in Mozart of an extensive self-borrowing that spans more than two instances is the aria “Non più andrai” from *Le nozze di Figaro*, which attained such popularity that Mozart re-used it both in the finale of the second act of *Don Giovanni* and in the Contredanse K. 609/1.

[17] Anecdotal findings suggest that when Mozart re-used longer melodic passages construable as self-quotations, he seldom preserved the original key. It seems that particularly in cases where the re-invocation of previous material is most literal, Mozart would take extra care to avoid an identity of key. Notable cases in point are the two melodies presented in Figure 2 and the refrain of the insert aria “Un bacio di mano” K. 541 in F major which was quoted later almost verbatim—however, in different keys (C and G major)—in the first movement of the “Jupiter” Symphony. Importantly, this observation refers to melodies re-used *en bloc* in different compositions. A different type of larger-scale melodic cross-reference is represented by melodic complexes re-invoked not as a whole—like in Figure 2—but rather by re-arranging sequences of smaller melodic elements derived from the original composition. Discussions of such recurrent melodic complexes are found, for example, in Eckelmeyer, 1980; Kelterborn, 1987; Jan, 1995.

[18] Compellingly put forth by Leonard Meyer (e.g., 1973, 1989) and Robert Gjerdingen (e.g., 1988, 2007), schema theory lays the foundations for a systematic exploration of the relation between common voice-leading schemata and their surface-level instantiations. While we expect a comprehensive investigation of correspondences between a given schema's instantiations and the choice of key to yield revealing insights, we confine ourselves in the present study to one melodic motive defined at the surface level.

[19] The embellished descent from scale degree  $\hat{6}$  to  $\hat{5}$ , common to all literal instances of the “Tamino” motive in Table 3—with the exception of K. 171/i—may be construed as the beginning of the “Prinner” schema, defined and named by Robert Gjerdingen (2007, pp. 45ff.). In all motive instances listed in the table (again, with the exception of K. 171/i), this melodic descent is doubled at the third (or the tenth) below by a parallel descent from scale degree  $\hat{4}$  to  $\hat{3}$  (located, as a rule, in an inner voice), which likewise constitutes an obligatory component of Gjerdingen's “Prinner”; moreover, all instances listed in Table 3—with the exception of K. 171/i—can be shown to feature also the second half of the “Prinner,” often with some modification. A comparison with the odd instance at the beginning of the String Quartet K. 171 is particularly intriguing in that it shows that near-identical instantiations of the motive at the surface level may be underlined by divergent, incompatible voice-leading schemata. Arguably, this points to a possible inherent failure of exclusively schema-oriented analysis to capture the complex network of associations taking place in a composer's mind, as Mozart seems here to bypass hierarchical schema-oriented derivation, directly associating instances of two different schemata with one another on the basis of their surface resemblance—an association corroborated by the choice of the motive's “idiomatic” key—E $\flat$  major—also for the deviating instance in K. 171/i. Ultimately, this case underlines the need for a theory of the musical surface. (For a recent discussion of the role of the musical surface in connection with theories of construction grammar, see Gjerdingen & Bourne, 2015.)

[20] A small group of instances corresponding to the *Tamino non-literal* prototype pose a special problem, being in a different key from that of the containing movement. We disregard these instances in the statistical evaluation, but list them among the motive's instances in Supplementary Table S3.

[21] Contemplating a possibly broader, intersubjective validity of key-related structure, we were able to locate no less than three works by Mozart's elder contemporaries featuring the "Tamino" motive in a nearly identical form to the one found in Mozart, moreover, sharing the same "idiomatic" key—Eb major: Carl Philipp Emanuel Bach's Trio-sonata in Bb major, H 584/Wq 158, ii; Johann Christian Bach's Symphony Op. 3, No. 4, ii; and Joseph Haydn's String Quartet Op. 17, No. 4, iii (Mozart's alleged familiarity with these works is discussed in Heuß, 1930; Abert, 1955–56, p. 364; Finscher, 1961; Warburton, 1984, vol. 26: pp. Iff.; Derr, 1997; Rom, 2009). Notably, all three works predate Mozart's earliest use of the motive in the String Quartet in Eb major, K. 160 (see Table 3); thus, each of them could potentially be his model. While this intriguing constellation may be construed to suggest an even older common model composition, the employment of this chromatically tinted six-note motive in conjunction with Eb major in the music of Mozart and his contemporaries may also be considered to indicate a broader validity of key-related structure, pertaining to a composers' community rather than a single composer. In the case of the "Tamino" motive, this association between key and musical content could be further linked to the historical tuning scheme of Eb major could (see discussion above).

[22] The two G-major symphonies by Haydn that begin with an *all-forte* theme are Hob. I:23 and Hob. I:27. Another symphony in G major, Hob. I:18, begins with a slow movement—however, its second movement, which arguably fulfills a "first-allegro" function in this cycle, has an *all-forte* opening theme.

[23] For evidence of Mozart's absolute pitch, see Deutsch, 2002. Regarding Mozart's supposedly eidetic musical memory, see Vetter, 1998.

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