# On the Fluidity of Consonance and Dissonance: the Influence of Musical Context

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Abstract

The consonance/dissonance (C/D) level of a triadic chord is not a fixed or absolute value. Rather, it is fluid, since C/D depends both on a chord's sonic characteristics and on the musical context in which it appears. To test the fluidity of C/D - the extent to which C/D perception is dependent on musical context - four types of chords, major, minor, augmented and diminished triads, were presented in isolation ("without musical context") and as part of a short cadence (IV-V-I, "with musical context"). The C/D level of each chord was judged, as was the overall C/D and pleasantness/unpleasantness (P/U) level of the cadences. When isolated, major triads were considered most consonant, followed by minor and diminished triads, while augmented triads were judged most dissonant. In the context of a musical cadence, this rank order remained the same, but augmented and diminished chords were evaluated as less or more dissonant depending on their functional position within the cadence (for instance, diminished triads were relatively consonant when on the subdominant, while augmented triads were relatively dissonant when on the tonic). These findings lend support to the hypotheses that: (a) the degree to which the harmonic function of a chord is familiar, and; (b) the degree to which a chord's stability (and hence also the listener's expectation) is violated contribute to the perception of C/D.

Keywords (5): consonance and dissonance: pleasantness: musical context: chord function: augmented and diminished triads

On the fluidity of consonance and dissonance: the influence of musical context

Consonance and dissonance (C/D) have over centuries been the central talking point in the discussion about the perception of chords. Consonance refers to the harmonious sounding of stimulating tones, and consonant sounds are often described as beautiful, pleasant, united, and smooth. Dissonance, meanwhile, refers to stimulating sound that has a rough quality, or to sounds that are unpleasant and inharmonious (Parncutt & Hair, 2011; Tenny, 1988). Listeners are able to judge almost instinctively whether a sound is consonant or dissonant, and the discernment of consonance and dissonance is an ability that does not require any particular skills or special knowledge. Nevertheless, for researchers, explaining or establishing theories of the phenomenon of C/D has proved to be a significantly more challenging task. The ancient Pythagoreans found that the consonant or dissonant sounds created by intervals are related to the frequency ratio between the two constituent notes of the intervals: the simpler the integer ratios between these notes are, the more consonant the intervals will sound. In the late 19$^{th}$ century, Helmholtz proposed that roughness caused by beating contributes to dissonance, and that therefore consonance is the absence of roughness (1877/1954). This theory was later developed by Plomp and Levelt (1965), and Kameoka and Kuriyagawa (1969), who demonstrated that the occurrence of roughness is related to the critical band. When the frequencies of two notes are within 25% of the width of the critical bands for those frequencies, the sound is dissonant, while the sound becomes progressively less dissonant as the two frequencies move further apart from, or closer towards, the 25% of the critical bandwidth.

An alternative account of C/D is Stumpf's theory of fusion (Boring, 1942: Schneider, 1997). "Fusion" refers to the experience of hearing well-blended, simultaneous sounds that are perceived as one whole, coherent sound. Two tones tend to fuse better when they have simpler integer frequency ratios, and the more fused two tones are, the more consonant they will be, whereas segregated sound that lacks fusion will be more dissonant. According to this theory, an octave is the most fused of all intervals, followed by the perfect fifth, and then by major and minor triads, a hypothesis that gained empirical support from a study conducted by DeWitt and Crowder (1987). Many recent C/D studies consider harmonicity to be an important factor in C/D perception (Bidelman & Krishnan, 2009; Cousineau, McDermott, & Peretz, 2012; McDermott, Lehr, & Oxenham, 2010; Tramo, Cariani, Delgutte, & Braida, 2001). These studies demonstrate that more harmonic intervals or chords will also be more consonant. In the case of intervals, those with simpler frequency ratios are said to be more harmonic, since the partials of two simple notes coincide to a greater degree and thus produce more regular patterns (Gill, & Purves, 2009). Tramo et al. (2001) showed that the autocorrelation histograms of the neural responses of cats to intervals finely mirror the patterns of the sound waves of those intervals, and a more regular pattern of neuron firing was observed when the cats were played a perfect fifth as opposed to a minor second. Some recent studies demonstrated that harmonicity is a greater contributing factor to the perception of consonance than roughness. McDermott et al. (2010) found a strong correlation between listeners' pleasantness ratings of intervals and chords on the one hand and harmonicity on the other, while the correlation between pleasantness ratings and the absence of roughness was weak. Similarly, a study by Cousineau et al. (2012) showed that, although listeners with amusia who were able to detect roughness tended to dislike it, they showed no preference for consonant or harmonic tones over more dissonant and inharmonic ones. This finding indicates that roughness is not by itself sufficient to account for C/D perception.

Despite the richness of studies on C/D perception, our theoretical understanding of the C/D of chords remains incomplete. Results from behavioral studies (Bidelman & Krishnan, 2011; Cook & Fujisawa, 2006; Johnson-Laird, Kang, & Leong 2012; Roberts, 1986) are consistent with the relative C/D order of the four triad types: listeners perceive major triads as being most consonant, followed by minor triads and diminished triads, while augmented triads are the most dissonant of all. One of the greatest difficulties for theory is the apparent discrepancy between the C/D of augmented and diminished triads. “Acoustic dissonance” for triads (Hutchinson & Knopff, 1979) is based on the difference between the dissonance factors for the three dyads that constitute each triad, together with the roughness of each complex tone. The calculated data is, it seems, mostly consistent with the relative C/D of chords in music theory. “Root ambiguity”, a theory suggested by Parncutt (1988. 1989), refers to the idea that a chord with a clearer root is perceived as more consonant. According to this theory, a major chord will sound more consonant than a minor chord because the major chord possesses a clearer root. Both “acoustic dissonance” and “root ambiguity” predict that the diminished chord will be the most dissonant type of triad; but this contradicts the evidence from behavioral data. Recent studies show that behavioral data on the rank order of the four triads may be explained by a different type of listener response and by other acoustic features of a chord. Bidelman and Krishnan (2011) found that chords that were judged to be more consonant elicited stronger “neural pitch salience”, which they calculated based on neural activity in the midbrain in response to the four chords. The ordering of the four chords, from the one that elicited the strongest neural pitch salience to the weakest, was consistent with the behavioural data. Likewise, McDermott et al. (2010) found a strong correlation between the listener’s preference for a chord and its harmonicity. However, we cannot definitively ascertain harmonicity’s role in determining the relative C/D of augmented and diminished chords, as diminished triads were not tested in the experiments.

The studies mentioned above focus on sensory consonance/dissonance, but when intervals and chords appear within the flow of music, their C/D is called “musical consonance/dissonance” or “tonal consonance/dissonance” (Krumhansl, 1990; Terhardt, 1984). It is thought that the perception of C/D depends not just on the sensory features of chords, but also on the musical context in which the interval or chord is presented. If this is the case, then factors such as: the principles of tonality; the musical context in which the chord appears; the listener's musical schema; the listener's familiarity with the style of music; and the music's acoustic properties may all play a part in shaping C/D perception (Cazden, 1980; Gardner & Pickford, 1943; Krumhansl, 1990; Lundin, 1947; Terhardt, 1984). Gardner and Pickford (1943, 1944) conducted a study to demonstrate the influence of musical context, in which they employed various chords (details not given) in different contexts and keys as musical stimuli. They found that context did indeed influence participants' judgements of the "dissonance-level" of target chords. Roberts (1986) also showed that chords sound more consonant when heard in a "traditional" harmonic progression as opposed to a "non-traditional" one. Unfortunately, these studies say little about precisely which elements of musical context might be responsible for influencing C/D judgements of chords, and nothing about how they might do so. The influence of context on the evaluation of dissonance was also observed in an experiment by Johnson-Laird et al. (2012), in which major triads, sevenths, minor sevenths, and minor triads were judged to be more consonant when heard in the context of a common harmonic progression than when in random, non-tonal sequences.

The effect of context on C/D perception may be attributable to harmonic expectations based on the listener's musical schema. One's musical schema is acquired as a result of enculturation, through a process of becoming familiar with a certain musical culture or genre. It is our musical schema that enables us to predict oncoming events, and to process these events on the basis of the knowledge we have stored in the schema (Bharucha, 1994). Empirical studies (Bigand, Madurell, Tillmann, & Pineau, 1999; Bigand & Pineau, 1997; Tillmann, Janata, Birk & Bharucha, 2008; Tillmann & Lebrun-Guillaud, 2006; Tillmann & Marmel, 2013) reveal that C/D judgements of expected chords, and in-tune or out-of-tune judgements of expected chords, are processed more quickly and accurately than unexpected ones. C/D of chords on the tonic - the governing and therefore most stable function, according to the theory of harmonic hierarchy - were judged faster and more accurately than that of chords on less stable functions such as the dominant and subdominant (Tillmann et al., 2008). Expected events are also thought to induce more positive affective reactions than unexpected events (Huron, 2006). Recent studies employing event-related potentials (ERPs) revealed that the early right anterior negativity (ERAN) is activated by unexpected chords in chords sequences, and acoustically identical chords generate different amplitudes in the ERP responses depending on the confirmation or violation of a chord's harmonic functions (Koelsch, Gunter, Friederici, & Schroeger 2000; Leino, Brattico, Tervaniemi, & Vuust, 2007; Loui, Grent-'t-Jong, Torpey, & Woldorff, 2005; Maess, Koelsch, Gunter, & Friederici, 2001). Also, target tones are recognized more accurately when they appear in familiar or meaningful contexts than when they appear in an unfamiliar or meaningless contexts (Dewar, Cuddy & Mewhort, 1977), and mismatch negativity (MMN), elicited by stimuli that deviate from other stimuli, was larger when this deviation occurred in familiar as opposed to unfamiliar contexts (Brattico, Näätänen & Tervaniemi, 2002).

The effect that one's schema has on perception is a part of cross-cultural differences in music perception. Listeners with different musical cultures have been shown to perceive some intervals in the chords of Western tonal music differently. A study by Maher (1976), which asked Canadian and Indian listeners to give twelve intervals "restful" or "restless" ratings, demonstrated that Indian participants generally rated intervals more "restful" than the Canadian group, and revealed that they did not judge that minor seconds and major sevenths were "restless" as Canadian listeners tended to. Attitudes to roughness and dissonant sound also vary from culture to culture. In Western tonal music, beating that causes roughness is normally avoided, as there exists an assumption that "rough sounds are inherently bad and unpleasant" (Vassilakis, 2005). Dissonance is associated with negative words (Costa Bitti, &

Bonfiglioli, 2000; Sollberger, Reber, & Eckstein, 2003), and dissonant music induces negative emotions and physiological responses that support this negative association (Dellacherie, Roy, Hugueville, Peretz, & Samson, 2010). By contrast, however, some musical cultures appreciate dissonance and beating, and positively encourage their appearance. For instance, the sitar and the shamisen, a traditional Japanese instrument with three strings, are both intentionally structured to create a buzzing noise (Malm, 2000); there is a method of tuning in Balinese gamelan designed to create beating when the orchestra play together; and there is a variety of Balkan singing called *gang*, in which a chorus alternately follows and then accompanies a solo singing section, singing the same melody just a major or minor second apart (Vassilakis, 2005). The people of the region consider these intervals "pleasant and desirable", although those from outside the region are more likely to fail to appreciate the resulting sound (Vassilakis, 2005). These examples help to convey something of the diversity and richness of C/D perception.

Another important issue concerning C/D is its relationship with pleasantness. Consonant sounds are often described as pleasant, and so it has been postulated that pleasantness should be considered an indication of consonance (Tenney, 1988). Many studies employing only non-musicians, or both musicians and non-musicians have shown that C/D and pleasantness/unpleasantness (P/U) are similar – that is to say, that there is a close match between C/D and P/U judgements (Guthrie & Morrill, 1928; Johnson-Laird et al., 2012; Plomp & Levelt, 1965; van de Geer, Levelt, & Plomp, 1962). However, differences between the perception of C/D and P/U have also been highlighted in a study by Guernsey (1928). In her study, musically trained participants judged octaves and perfect fifths as being the least pleasant intervals, despite their also being judged the most fused and smooth. The present study explores whether, as most studies suggest, the perception of C/D and P/U for triads is positively correlated by canvassing the judgements of participants with a moderate amount of musical training and experience.

Regarding the influence of musical experience on C/D judgements, both behavioral and neuroscientific studies show that musicians are more sensitive to C/D than non-musicians (Brattico, Pallesen, Varyagina, Bailey, Anourova, Järvenpää, Eerola, Tervaniemi, 2009; Itoh, Suwazono, & Nakada, 2010; Roberts, 1986; Rogers, 2010; Schön Regnault, Ystad, & Besson, 2005). Further, musicians are more likely to rely on sensing the harmonicity of a chord in order to judge its C/D than their non-musician counterparts (Kung, Hsieh, Liou, Lin, Shaw, & Liang, 2014; McDermott, Lehr, & Oxenham, 2010). On the other hand, no difference between musicians and non-musicians were found in certain other cases. For instance, there was "no reliable effect" of musical experience on the dissonance ratings of chords (Johnson-Laird et al. 2012), no difference between the C/D and pleasantness judgements of musicians and non-musicians when chords were presented in a context (Roberts, 1986), and no difference between musicians' and non-musicians' judgements of the semantic connotations of an interval's C/D (Costa et al., 2000). These examples emphasize both the rigidity and the fluidity of C/D perception. This study will focus in particular on the influence of familiar harmonic functions on the perception of chords, using participants who have had a moderate amount of musical training and who are familiar with tonal cadences.

**Present Study**

As Lundin (1947) claimed, the C/D levels of chords are neither fixed nor absolute, but change according to context. It is true that each chord may have a certain standard level of C/D based on its sensory C/D. However, the effects of musical context and of the listener's musical schema mean that there is fluidity to C/D judgements in the case of all chords. The purpose of the present study is to investigate the influence of musical context, and in particular the influence of harmonic function, on the listener's C/D and P/U perceptions of a triad. Experiment 1 tested listener's C/D perceptions of major, minor, augmented, and diminished triads in isolation. In Experiment 2, all triads were allocated a different position in the short sequence IV-V-I in both major and minor keys. The results of the two experiments will be compared in order to assess the "fluidity" of the chords – that is, the extent to which the level of each chord's C/D varies according to whether it appears in isolation or in a musical context.

Although musical context is considered to be the key factor in determining musical C/D, it has not been clearly specified what "musical context" connotes, nor what or how the various components of musical context influence C/D judgements. In the case of a short harmonic progression consisting of several chords, musical context can be defined as the relationship between the target chord, and the preceding and succeeding chords. For short harmonic progressions, then, sensory relatedness and the hierarchy between notes and chords in a local context, and the function of chords in a global context, together comprise the musical context. In the case of longer, more complicated musical works, melodic anchor and rhythmic patterns will be part of the musical context as well. This study considers musical context in two ways: a musical context in which the same chords are given different harmonic functions; and the presence and absence of musical context - that is, chords in isolation and chords that appear in some musical context. Experiment 2 examines the fluidity that results from the same chord being heard in different functions, and later the results of Experiments 1 and 2 will be compared in order to analyze whether and to what extent context influences fluidity – that is to say, how the C/D of chords varies according to whether they are heard in a musical context.

<Insert Figure 1>

**Hypotheses: Fluidity 1. Different Harmonic Function**

In Experiment 2, each triad was allocated a different position in the short sequence IV-V-I in both major and minor keys (major and minor triads appeared only in sequences in major or minor keys respectively). The appearance of an augmented or diminished chord is expected in certain progressions, since both chords have certain “expected” harmonic functions. In such cases, the chord will be more familiar and therefore less dissonant-sounding than the same chord in an aberrant or unfamiliar chord progression, or if it occupies an unfamiliar function. There are three possible models for explaining how augmented and diminished chords may be perceived differently depending on harmonic function: the familiar harmonic function model; the tonal stability model; and the position of the fifth note of the target chord model.

1. **The Familiar Harmonic Function Model**

Previous studies (Koelsch, Gunter, Friederici, & Schroeger, 2000; Leino, Brattico, Tervaniemi, & Vuust, 2007; Loui, Grent-‘t-Jong, Torpey, & Woldorff, 2005; Maess, Koelsch, Gunter, & Friederici, 2001) show that the degree of expectation for a chord varies according to its harmonic functions. In other words, chords are expected in a certain context with a certain harmonic function, but the acoustically identical chord can seem unexpected when it performs an uncommon harmonic function. These studies used ERPs, and demonstrated that the Neapolitan chord elicits a larger amplitude of the ERAN when it appears on the unexpected tonic function than when on the expected subdominant function (Koelsch et al, 2000; Leino et al, 2007; Loui et al, 2005; Maess et al, 2001). On the basis of this, the familiar harmonic function model predicts the following: augmented and diminished chords will sound most consonant when heard on their most familiar and conventional functions. In music theory, augmented chords appear in a minor key as the mediant (Piston, 1950), though in practice the mediant is quite an uncommon chord. Augmented chords are often used as a substitute for a dominant chord, or as neighbouring or passing chords (for example, within the progressions I – I+ - IV, and I –I +- I), in order to give the music a chromatic sound and to embellish the harmony (Gauldin, 1997). The most familiar function for augmented triads is the dominant, followed by the tonic. Diminished triads can act as leading note chords that precede the tonic and the end of the cadence, and have a dominant function in this context. They can also appear as the supertonic in a minor key (Andrews, 1950), and in this context they have a subdominant function. This familiar harmonic function model predicts that augmented chords will sound more consonant when they appear on the dominant or tonic, and that diminished chords will be more consonant when on the dominant or subdominant. Conversely, they should sound most dissonant when occurring in any other function.

## 2. The Tonal Stability Model

Turning now to the second model, which is based on the notion of the tonal hierarchy of chords, and according to which C/D and P/U judgements are susceptible to the influence of the tonal stability of chords rather than being determined by the familiarity of their function. The second model supposes that an unexpected chord sounds more dissonant when it appears on a more stable function than when on a less stable function, because the violation of stability will be greater with the former. This idea is based on the theory of the psychological tonal hierarchy and stability of chords (Bharucha & Krumhansl, 1983; Krumhansl, 1990). In Western tonal music, there are 12 tones in each octave, and chords can be built up on each tone. However, these 12 tones or chords do not appear an equal number of times in most pieces of music, but rather some tones and chords - such as tonic, dominant, and subdominant - occur more frequently than others. These dominating tones and chords are more important, and are described as stable because they help to establish the sense of key and function as a cognitive reference (Bharucha & Krumhansl, 1983; Krumhansl, 1990). A series of studies by

Krumhansl employing the probe-tone technique demonstrate the psychological tonal hierarchy that exists in a listener's musical schema. Her studies reveal that listeners give the highest ratings of fitness to tonic tones (Krumhansl & Kessler, 1982) or chords (Krumhansl, 1990), followed by dominant and subdominant tones or chords. Bigand (1997) also provides empirical evidence of a correlation between the level of a tone in a tonal hierarchy and that tone's stability. This psychological tonal hierarchy is generally in accordance with music theory, and with findings concerning the frequency of a chord's occurrence as investigated by Budge (1943). Chords rooted in a tonic tone (e.g., C-E-G, C-E-G-B in the key of C major) account for 41.79% of the musical pieces she examined, followed by 31.68% for chords with a dominant tone root, and 8.45% for chords with a subdominant tone root (Krumhansl, 1990). Tonic tones or chords are the most frequently occurring, and are therefore the most stable in the hierarchy. This dominance of the tonic can be represented by other subjective measures (Tillmann, 2008). Of all chords, tonic chords elicit the greatest sense of completion (Tillman & Lebrun-Guillaud, 2006), and the lowest levels of tension (Bigand, Parncutt, & Lerdhal, 1996). Tones and chords with more stability are processed more quickly and accurately (Bigand, Tillmann, Poulin-Charronnat, & Manderlier, 2005 ;Bigand, Poulin, Tillmann, Madurell, & D'Adamo, 2003; Tillmann, & Marmel, 2013), and judgements of C/D are processed most quickly when the target chord is on the tonic, followed by the dominant, and most slowly when on the subdominant (Bigand & Pineau, 1997; Tillmann, Janata, Birk, & Bharucha, 2008).

Stability is also attributable to the sensory C/D of chords (Bigand et al., 1996; Dibben, 1999), and roughness especially is an important contributing factor. Chords with more roughness induce higher musical tension (and less stability) than those with less roughness (Bigand et al., 1996), and musical tension is often considered the opposite of resolution or stability (Krumhansl, 1990). Chords containing the perfect fifth have relatively simple frequency ratios and are therefore judged as being stable and consonant, even in atonal music (Dibben, 1999). There is a correlation between sensory C/D and stability: the more consonant a sound is, the more stable it sounds to the listener. Therefore, being consonant is a prerequisite for tonal stability.

The second model supposes that an unexpected chord, one that does not normally appear in that context, will violate tonal stability. The violation of tonal stability may be bigger when the chord occurs on a more stable function than when it occurs on a less stable function. Thus, an unexpected chord on the tonic is likely to sound particularly dissonant because of the violation of tonal stability, while a similar chord on the subdominant function will be less so due to it being less of a violation of stability.

### 3. The Position of the Fifth Note Model

The third model to consider is the position of the fifth note of the target chord in the context of the scale. This model predicts that the C/D of augmented and diminished chords may be influenced by the importance of the fifth tone of the chord, which is replaced by an augmented or diminished tone. In Experiment 2, the same target chords are allocated to one of three unexpected positions in a short harmonic progression, IV-V-I. For example, an augmented chord, C- E-G# appears on IV when the sequence is in the key of G major, on V when it is in the key of F major, and on I when it is in the key of C major (See Figure 1). An acoustically identical chord can appear in different keys, and can as a consequence perform different harmonic functions. In addition, the position of a chord’s constituent tones in the tonal hierarchy will change depending on the key. These facts indicate that the tonal hierarchy is dependent on context rather than on the acoustic sonority of a chord (Bigand, 1997; Tillmann, 2008). To illustrate this further, the fifth note of a C major chord, G, is a tonic tone when in the key of C major; but it becomes a supertonic when in the key of F major, and so its importance in the hierarchy changes accordingly. In augmented and diminished chords, however, the fifth note (G sharp and G flat respectively when the root is C) does not feature either in the C major scale or the C minor scale, and this deviation violates the listener's expectations. On this basis, the third model hypothesises that a chord whose fifth note is replaced and violated by an augmented or diminished note will be more dissonant when the replaced tone has a more important position in the tonal hierarchy, because the violation of expectation will be greater in such a case. The fifth note of a chord will be the tonic when that chord is on IV, or the supertonic when on V, or the dominant when on I - so the prediction is that unexpected augmented and diminished chords will sound most dissonant when they are on the subdominant (IV) followed by when they are on tonic (I), and most consonant when on the dominant (V).

Table 1 summarizes the three hypotheses regarding the effect on C/D of the function of a chord. The first hypothesis predicts that a chord will sound more consonant when it appears on the most frequent, and therefore most familiar, function. Augmented chords are thus expected to be more consonant when on the tonic or dominant, and less consonant on the subdominant. Diminished chords, meanwhile, may sound most consonant when heard on the dominant, and less consonant when on any other functions. The second model supposes that augmented and diminished chords will sound most dissonant when they occur on the tonic because of the greater violation of stability that this would represent. The third model posits that the C/D of augmented and diminished chords is influenced by the importance of the fifth note of chords in a key context: a chord will sound more dissonant when the fifth note of the chord being replaced by either an augmented or diminished tone has a more important position in a tonal hierarchy. According to this model, both augmented and diminished chords are most consonant when they appear on the dominant, followed by the tonic, and the least consonant when on the subdominant. Note that the second and third models consider different aspects of the tonal hierarchy. The second model concerns the stability of the function performed by the chord, while the third model deals with the importance of the fifth tone of augmented or diminished chords in a key context.

<Insert Table 1>

**Hypotheses: Fluidity 2. The Presence and Absence of a Musical Context**

The C/D ratings for four types of chord in Experiment 1 (without context) and the ratings for Experiment 2 (with context) will be compared in order to examine the second variety of fluidity: the influence of context on the C/D level of a chord. Expectedness may play an important role in shaping the influence of context on C/D perception. Studies by Roberts (1986) and Johnson-Laird, Kang, and Leong (2012) found that chords were judged to be more consonant when appearing in more orthodox, expected contexts. In terms of the present study, then, we can expect that the same chord will sound more consonant when appearing in a more expected musical context than when heard in isolation, and it will sound more dissonant in unexpected musical contexts than in isolation. By contrast, the C/D level of a chord in isolation can only be influenced by its acoustic features as it is not subject to the effects of context and expectedness.

The influence of context is expected to vary according to the type of chord in question. The C/D level of augmented and diminished chords both with and without context is expected to vary more than the C/D level of major and minor triads. This is because augmented and diminished triads are less stable (Krumhansl, 1990), and have less clear roots than major and minor triads (Parncutt, 1988). Also, unlike both major and minor triads (e. g. C-E-G and C-E♭-G), the augmented (e.g., C-E-G#) and diminished (e.g., C-E♭-G♭) triads used in this study are not comprised solely of tones from the key scale, and neither can they be tonic chords of the key. These factors help to contribute to the wider range of C/D judgements that these chords elicit compared to major and minor chords.

## Experiment 1. Chords Without Musical Context

### Method

#### Participants

Thirty-six adults (Male: 16, Female: 20. Age range: 21-74 years, with a mean age of 33.72 years), all with a moderate amount of musical experience, were recruited. There were 18 participants who had had at least 5 years' worth of music lessons in some form or other, while a further 11 participants were either music students or had already gained degrees in music. 7 participants had not received any formal music lessons or training, but played an instrument or listened to music on a daily basis.

#### Materials

Materials consisted of major, minor, augmented and diminished triads built on 12 scale degrees (C4: 261.63 Hz, C#4, D4, D#4, E4, F4, F#4, G4, G#4, A4, A#4, B4: 493.88 Hz), all of which were played in root and close position, making a total of 48 triads. Each triad was created by a software program called Cubase using a piano sound, YAMAHA S90ES Piano. The duration of each chord was 1.10 seconds.

#### Procedure

Forty-eight single triads in root position and close position, each one either a major, minor, augmented or diminished triad, were played in a random sequence using all 12 keys. Participants were asked to judge whether each chord was either consonant or dissonant by pressing buttons on a computer keyboard as quickly and accurately as possible. The next chord would appear after the participant had pressed the "continue" button. Participants' response times were recorded.

## Results and Discussion

Table 2 shows the median, 25th and 75th percentiles of C/D judgements for each chord. As can be seen, major triads were judged the most consonant type of triad, followed by minor triads, and then diminished triads, while augmented triads were considered the most dissonant triad. This result reconfirms those of similar experiments in the past (Bidelman & Krishnan, 2011; Cook & Fujisawa, 2006; Johnson-Laird et al., 2012; Roberts, 1986), and contradicts the rank order of calculated dissonance value by Hutchinson and Knopff (1979). Friedman's non-parametric test was used to compare the frequency of "Consonant" responses for each chord, averaged across 12 keys per participant as the data was not normally distributed. The results show that there are statistically significant differences between listeners' judgements of each chord, $\chi^2 = 75.47$, $df = 3$, $p < .001$. The Wilcoxon sign-ranked test shows that judgements for major triads were significantly higher – that is to say, participants judged them to be significantly more consonant - than for minor triads, $z = -3.40$, $n = 36$, $p < .001$, two-sided, augmented triads, $z = -5.17$, $n = 36$, $p < .001$, two-sided, and diminished triads, $z = -4.74$, $n = 36$, $p < .001$, two-sided. As for minor triads, judgements were significantly higher than for either augmented triads, $z = -5.04$, $n = 36$, $p < .001$, two-sided, or diminished triads, $z = -3.96$, $n = 36$, $p < .001$, two-sided. Wilcoxon sign-ranked test also shows that judgements for diminished triads were higher than for augmented triads, $z = -4.36$, $n = 36$, $p < .001$, two-sided.

Reaction time (the length of time between the start of the sound stimulus and the participant's response) was analyzed using a one-way ANOVA for Repeated Measures

(Chord Type) after log-transformation. However, no main effect of Chord Type on response time was found ($p$ = .884).

<Insert Table 2>

**Experiment 2. Chords with Musical Context**

Experiment 2 examined differences in the perception of the same four triads from Experiment 1 (major, minor, augmented and diminished triads) when these are given different harmonic functions. All triads were allocated a variety of different positions in the short sequence IV-V-I in both major and minor keys (major and minor triads appeared only in sequences in major or minor keys respectively).

## Method

### Participants

The participants were the same individuals who took part in the previous experiment.

### Materials

We used 72 chord sequences. Each chord sequence was preceded by a diatonic scale in order to present the key to the participant, and was then followed by the following three chords: IV-V–I (See Figure 1). One of the chords was the target chord. Triadic chords with roots of C, F♯, A, or E♭ - these being the most distant tones in the circle of the fifths - were chosen as target chords to cover all 24 keys (Table 3). For example, a C major target chord is capable of fitting into three different keys depending on its function: the key of C major when on the final tonic chord (I) of the sequence IV-V-I; the key of F major when on the dominant (V); and the key of G major when on the subdominant (IV).  Thus, it is possible to create sequences in all 24 keys using triads built on only on the roots of C, F#, A, and E♭. All chord sequences contained either one augmented triad (24 sequences), or one diminished triad (24 sequences), or a major or minor control triad (24 sequences). Target chords were put in either the tonic, the dominant or the subdominant position in each chord sequence (Figure 1). It is true that, in normal harmony practice, augmented or diminished chords do not appear in the cadence IV-V-I. Nonetheless, the rationale behind intentionally allocating them to the IV-V-I sequence was that we would be able to see the effect of function more clearly.

<Insert Table 3>

All sound materials were sourced from Cubase, and a piano sound, YAMAHA S90ES Piano was used. The duration of each sequence was approximately 7 seconds in total: the scale was 2.20 seconds, and the first chord appeared after 0.85 seconds of silence. Each chord was 1 second long, and there was 0.50 seconds' silence between them. The interonset interval was 1.50 seconds. The aim was to present a sequence that allowed participants enough time to judge each chord, but that was not so slow that they would have trouble perceiving the three chords as a cadence. The tempo and loudness of all materials were kept constant throughout.

**Procedure**

Seventy-two chord sequences consisting of a scale and three chords were presented. Two tasks were given to participants: to give C/D ratings for each individual chord within the chord sequence, and to give C/D and pleasantness ratings for the entire chord sequence. The first task for participants was to judge whether each of the three chords they heard was either consonant or dissonant as quickly and accurately as possible, which they did by pressing a button directly after each chord was played. One of these three chords was either augmented or diminished (target chords), or a control chord (major or minor). Participants were not informed prior to hearing which of the chords would be the target chord. The chords in the sequence appeared successively and the listener was not able to pause the sequence, meaning that they had to respond before the next chord. The second task was that, after each sequence had finished, participants rated the C/D and P/U levels of the whole sequence on a 7-point scale, with 1 being extremely dissonant/unpleasant and 7 being extremely consonant/pleasant.

**Design**

Combining the manipulation of Mode (two levels: major and minor), Chord Type (three levels: augmented triads, diminished triads, and controls), and Functions (three levels: tonic, dominant, and subdominant) results in a possible 18 conditions for the four target chords. There are 72 sequences in total. In the analysis, responses were averaged across the different pitches that were used, resulting in 18 responses per participant.

## Results and discussion

### C/D judgments of the target chords

Listeners' judgements of the target chords as being either "Consonant" or "Dissonant" were recoded as 0 or 1, respectively. The frequency of each response was averaged across the keys per 18 conditions, and the resulting data was not normally distributed. Hence, a non-parametric test was performed to examine the influence of three factors - Mode, Chord Type, and Function - on C/D judgements, and their interactions with each other. The Wilcoxon signed rank test showed no statistically significant differences between major and minor modes. As for Chord Type, Friedman's two-way analysis of variance by ranks revealed significant differences in C/D judgements depending on Chord Type, $\chi^2 = 59.61$, $df = 2$, $p = .001$. Post-hoc analysis with the Wilcoxon signed-rank test was conducted with a Bonferroni correction applied. As a result, the alpha level for statistical significance was set at $\alpha = .017$. No significant difference in C/D judgements between augmented and diminished triads was found. However, there were significant differences between augmented and control triads (major and minor triads), $z = 5.19$, $n = 36$, $p < .001$, and between diminished and control triads, $z = 5.17$, $n = 36$, $p < .001$. These results indicate that the control triads were more consonant than either augmented or diminished triads. An application of Friedman's test also revealed statistically significant differences between tonic, dominant, and subdominant, $\chi^2 = 7.32$, $df = 2$, $p = .026$, and post-hoc analysis with the Wilcoxon signed-rank test showed that the subdominant was more consonant than the dominant, $z = 2.46$, $n = 36$, $p = .0014$, though there was no difference between either the tonic and the dominant, or the tonic and the subdominant. In terms of the interaction between Chord Type and Function, no significant difference was found in either augmented or control triads (major and minor triads). There were statistically significant differences in C/D judgements for diminished triads depending on Function, $\chi^2 = 18.43$, $df = 2$, $p < .001$, with diminished triads on the subdominant judged to be more consonant than those on either the tonic, $z = 3.18$, $n = 36$, $p = .001$, or the dominant, $z = 3.33$, $n = 36$, $p = .001$. As for the triple interaction between Mode, Chord Type and Function, the application of Friedman's test in augmented and control triads showed no significant difference between Mode and Function. However, there were significant differences in diminished triads both in major modes, $\chi^2 = 12.80$, $df = 2$, $p = .002$, and minor modes, $\chi^2 = 15.50$, $df = 2$, $p < .001$. Post-hoc tests revealed that C/D judgements for diminished triads in major modes on the subdominant were higher than those on either the tonic, $z = 2.56$, $n = 36$, $p = .010$, or the dominant, $z = 2.51$, $n = 36$, $p = .012$. Equally, in minor modes, diminished triads on the subdominant were more consonant than those on either the tonic, $z = 2.73$, $n = 36$, $p = .006$, or the dominant, $z = 3.08$, $n = 36$, $p = .002$. The results reveal the strong tendency among participants to perceive diminished triads as being more consonant when on the subdominant.

Participants' reaction times were also analyzed after log-transformation. A three-way repeated measures ANOVA indicated a significant main effect of Function: $F(1.68, 59.02) = 14.720$, $p < .001$, partial $\eta^2 = .29$. Participants responded quickest to chords on the dominant ($p < .001$), followed by those on the tonic, and lastly on the subdominant.

**Overall consonant/dissonant ratings**

After listening, participants rated C/D and pleasantness levels. A three-way ANOVA with repeated measures was performed to test the effect of Mode (major vs. minor), Chord Type (augmented, diminished, and control), and Function (tonic, dominant, subdominant) on ratings and reaction times. There was a significant main effect of Mode: $F(1, 35) = 11.29$, $p = .002$, partial $\eta^2 = .24$, as sequences in major keys were rated more highly (in other words, were considered more consonant) than those in minor keys. Sequences containing only major and minor triads were rated higher than those containing augmented or diminished triads ($p < .001$); Chord Type: $F(1.24, 43.39) = 155.21$, $p < .001$, partial $\eta^2 = .81$. There was a significant interaction between Mode and Chord Type: $F(2, 70) = 12.52$, $p < .001$, partial $\eta^2 = .26$ (Figure 2). As for the effect of Function, this had a significant main effect: $F(2, 70) = 15.50$, $p < .001$, partial $\eta^2 = .30$. There was significant interaction between Chord Type and Function: $F(3.32, 116.19) = 15.11$, $p < .001$, partial $\eta^2 = .30$. The mean ratings are shown in Figure 3. Sequences containing augmented triads on the tonic in a major context were rated significantly lower (more dissonant) than those on other functions ($p < .001$), while sequences containing diminished triads on the subdominant in both major and minor contexts were significantly more consonant than those on either the tonic or dominant ($p < .001$), replicating the results of the evaluations of specific target chords reported above.

As for the log-transformed reaction times for C/D ratings, there was a significant main effect of Chord Type: $F(2, 70) = 18.565$, $p < .001$, partial $\eta^2 = .33$. Sequences that contained control chords as targets (major and minor triads) were rated quickest among the three types of chord, and significantly quicker than diminished chords ($p < .001$). An interaction between Mode and Chord Type was also found: $F(2, 70) = 9.04$, $p < .001$, partial $\eta^2 = .20$: the effect of Chord Type varied according to Mode. Control chords in a major context (all of which were major triads) were processed significantly quicker than were augmented and diminished triads ($p < .001$), although there was no difference in reaction times between sequences containing minor, augmented or diminished triads.

<Insert Figure 2 & 3>

**Overall pleasantness ratings**

A three-way ANOVA with repeated measures (Mode 2, Chord Type 3, Function 3) was performed on the P/U ratings. All main effects were found to be significant: Mode: $F(1, 35) = 4.51$, $p = .041$, partial $\eta^2 = .11$, Chord Type: $F(1.21, 42.62) = 88.37$, $p < .001$, partial $\eta^2 = .71$, Function: $F(2, 70) = 17.51$, $p < .001$, partial $\eta^2 = .33$. The general trend was very similar to that for overall C/D ratings. There were significant interactions between Mode and Chord Type: $F(2, 70) = 11.22$, $p < .001$, partial $\eta^2 = .24$ (Figure 4), and between Chord Type and Function: $F(4, 140) = 18.072$, $p < .001$, partial $\eta^2 = .34$ (Figure 5). The effect of Chord Type varied according to Function, as sequences featuring augmented triads on the tonic were significantly different from those with the same triads on the dominant and subdominant: $F(1, 35) = 17.13$, $p < .001$, partial $\eta^2 = .32$. Also, the sequences with diminished triads on the subdominant were judged more pleasant than those with diminished triads on either the tonic or the dominant: $F(1, 35) = 38.96$, $p < .001$, partial $\eta^2 = .51$.

As for log-transformed reaction times, only a significant main effect of Chord Type was found: $F(2, 70) = 13.23$, $p < .001$, partial $\eta^2 = .27$. Responses for control chords were quickest among the three types of chord, and were significantly quicker than responses for augmented triads ($p < .001$).

<Insert Figure 4 & 5>

**Correlation between C/D and P/U**

The results of the three-way ANOVA with repeated measures, one for each overall C/D and P/U evaluation, indicate that both have identical main effects (Mode, Chord Type, and Function) and interactions (Mode and Chord Type, and Chord Type and Function). Pearson's product-moment coefficient revealed a very strong positive correlation between the mean evaluation of C/D and P/U: $r(18) = .99$, $p < .001$. Additionally, the data we assessed on the correlation between participants' C/D and P/U ratings revealed interesting individual differences. In short, not all participants gave similar ratings to C/D and P/U. The range of coefficient values run from -.092 to .980, with the median being .831. For most participants, C/D and P/U ratings were highly correlated ($p = .001$ to $p = .015$). However, for a few participants (four out of 36), C/D and P/U were evidently different qualities, demonstrated by the fact that their results show no correlation between C/D and P/U ($r < .50$, $p > .05$). Nevertheless, C/D and P/U ratings are generally very similar overall, and it can be supposed that most participants perceived them similarly. This supposition is also consistent with the findings of Guthrie and Morrill (1928), who noted that judgments of the consonance and pleasantness of intervals were very similar.

**Chords Without and With Musical Context**

A non-parametric test compared the C/D judgments of chords in isolation (Experiment 1) with those of chords in context (task 1 in Experiment 2, target chords), in order to see how judgments differ between chords without and with musical context. The

Wilcoxon Signed Rank test was performed to compare eighteen pairs (two Modes, three Chord Types, and three Functions) with a Bonferroni correction applied, resulting in an alpha level for statistical significance that was set at $\alpha = .00278$. The results for significant pairs are shown in Table 4. There was no statistically significant difference between control triads, with the exception of minor triads on the subdominant, which were more consonant than when in isolation, $z = 3.29$, $n = 36$, $p = .001$. As for augmented and diminished triads, all were significantly different, except for augmented triads on the dominant in both major and minor modes. For most of the pairs, the results were positive: that is, chords were more consonant when appearing in context than when in isolation. However, the results for diminished triads indicate that diminished chords on the dominant in both major and minor modes were judged more dissonant when heard in context.

<Insert Table 4>

## General Discussion

Two experiments were conducted to investigate the influence of musical context on the C/D perceptions of four triads. In Experiment 1, participants were presented with four types of triad without musical context, and they were asked to judge whether these were consonant or dissonant. Major triads were judged the most consonant, followed by minor, and then by diminished. Augmented triads were judged the most dissonant. This result is consistent with previous studies such as Bidelman & Krishnan (2011), Cook & Fujisawa (2006), Johnson-Laird et al. (2012), and Roberts (1986).

Experiment 2 investigated the influence of context and function on the C/D and P/U levels of chords. Participants judged whether each chord of the three-chord sequences they were played was either consonant or dissonant (task 1), and rated C/D and P/U levels of the whole sequences (task 2). Across all tasks, the control chords (major and minor triads) were rated higher for consonance and pleasantness than either augmented and diminished chords. Major chords were in addition rated higher for consonance and pleasantness than minor chords, and were judged most quickly, corroborating the results of similar experiments that have demonstrated that more expected stimuli are processed more quickly (Bigand et al., 1999; Bigand & Pineau, 1997; Tillmann et al, 2008; Tillmann & Lebrun-Guillaud, 2006).

**Fluidity 1: Different Harmonic Function**

The familiarity model predicts that a chord will sound more consonant when it is heard on a more familiar harmonic function. Since, for example, the dominant or tonic is a familiar function for augmented chords, and the dominant or subdominant are familiar functions for diminished chords, the familiarity model will predict that these chords will sound more consonant than the same chords on a less familiar function. By contrast, the tonal stability model predicts that augmented or diminished chords will be most dissonant when on the tonic, followed by the dominant, and most consonant when on the subdominant. The third model based on the position of the fifth note in a scale predicts that the target chord will sound most consonant on the subdominant, followed by the tonic, and most dissonant when on the dominant. This prediction derives from the idea that a chord is more dissonant when its fifth note, which is violated by an augmented or diminished tone, has more importance in tonal hierarchy

The results of Experiment 2 show that the C/D levels of acoustically identical chords vary according to harmonic function, a finding that closely matches the previously mentioned hypothesis that the same chord will provoke different expectations and brain responses when it fulfils different harmonic functions (Koelsch et al., 2000; Leino et al., 2007; Loui et al., 2005; Maess et al., 2001). The difference between functions was very clear in the case of diminished chords in both major and minor contexts. Both judgements for target chords (task 1 in Experiment 2) and ratings of whole chord sequences for C/D and P/U (task 2 in Experiment 2) show that diminished chords on the subdominant were consistently judged more consonant and pleasant than the same chord appearing in any other function. These results for diminished chords could be ascribed to familiarity: diminished triads often appear as a supertonic chord in a minor key, and a diminished chord on the subdominant is identical to a diminished seventh chord built on the supertonic (II) of the key without the root (Parncutt, 2006). In this context, diminished triads will often be followed by V and I chords to make a common harmonic progression, which is the same progression employed in this experiment: IV-V-I. This influence of familiarity seems to be consistent with the results of previous (Koelsch et al., 2000; Leino et al., 2007; Loui et al., 2005; Maess et al., 2001), in which the Neapolitan chord appearing on an unexpected function (the tonic) triggers larger negativities than the same chord on an expected function (the subdominant).

As for C/D judgements of augmented chords (task 1 in Experiment 2), no significant differences were found in the C/D judgements between functions. This may be due to the fact that the dissonant characteristics of the augmented chords were too strong to be influenced by their function, a postulation that is consistent with Johnson-Laird et al.'s (2012) finding that non-tonal chords with a strong acoustic character are less likely to be influenced by context. However, augmented triads on different functions did receive different ratings, with sequences containing augmented triads on the tonic in a major key (task 2 in Experiment 2) receiving the lowest C/D and P/U ratings. This may be due to there being a greater violation of expectation for augmented triads on the tonic, an idea that supports the second model based on the stability of chords. Diminished chords on the tonic were likewise judged to be less consonant, though this was also not statistically significant. Perhaps augmented and diminished chords on the tonic represented a larger violation because the last chord of the sequence was expected to be consonant, in order to provide a proper end to the cadence. This larger violation of expectation may also be due in part to the fact that the tonic is the most stable function (Bharucha & Krumhansl, 1983; Krumhansl, 1990), that there is a greater expectation that a cadence will end on the tonic than in any other way (Tillman & Lebrun-Guillaud, 2006), and that the sense of key and harmonic context has to be established well towards the end of a chord sequence (Koelsch et al., 2000). A greater violation of stability occurred in the case of augmented triads on the tonic because, for a variety of reasons, the expectation for a stable tonic to complete the cadence is greater than it is with the other two functions.

By contrast, the results for augmented triads do not lend support to the familiarity model. This may be owing to the fact that augmented triads on the tonic are familiar only in very particular circumstances, and that these were not to be found in the experimental stimuli. The tonic in the stimuli sequences of this experiment was in all cases the last chord of the sequence. However, augmented chords typically only appear on the tonic at some point within a sequence in order to lend the phrase a chromatic sound, and this of course represents a very different usage for the augmented chord.

The result that diminished chords on the subdominant were consistently perceived as more consonant than the same chords on the other two functions lend partial support to the third model, which is concerned with the position of the fifth note in the scale. This model predicts that the target chord will sound most consonant on the subdominant, followed by the tonic, and most dissonant when on the dominant. Although there is no statistically significant difference between the overall ratings for C/D and P/U for a diminished chord on the tonic and the same chord on the dominant, the chord was judged slightly less consonant and less pleasant on the dominant when the fifth note was the supertonic than it was on the tonic when the fifth note was the dominant, a finding that is consistent with the position of the fifth model. However, the results for augmented chords, which showed that these were most dissonant when on the tonic, do not conform to this model's predictions. It is difficult to know whether to conclude that there is some difference between the perception of the consonance of augmented and diminished triads that renders this model only partially valid, or whether the results for augmented chords in fact indicate that the model is wholly invalid.

In short, Experiment 2 confirmed that C/D is fluid, and that the C/D levels of chords vary according to harmonic function. The results for diminished triads are consistent with all three hypotheses, while the results for augmented triads are consistent only with the second model based on the stability of the function of a chord. The difference between the results obtained for augmented triads and those obtained for diminished triads may be due to the fact that the diminished triad and the augmented triad are very different types of chord: each has its own unique acoustic properties, and each has a particular role to play in musical harmony.

**Fluidity 2: Presence and Absence of a Musical Context**

The comparison between chords in isolation (Experiment 1) and chords in a musical context (task 1 in Experiment 2) reveals the influence of context on C/D perception for both diminished and augmented chords. Augmented triads on the tonic and subdominant were more consonant when occurring in a context than when in isolation. The influence of context on the C/D levels of diminished triads varied: diminished chords on the dominant were more dissonant in a context than in isolation, but when they appeared on the tonic and subdominant they were more consonant in a context. As for control chords, with the exception of minor chords on the subdominant, no difference in C/D judgements was evinced between major and minor triads heard in isolation and in a musical context.

Both augmented and diminished triads were judged more consonant when they appeared on the tonic or the subdominant than when in isolation. However, C/D judgements for augmented and diminished chords differ from one another when it comes to the dominant: there is no significant difference between the C/D levels of augmented chords on the dominant and the same chords in isolation, whereas diminished chords on the dominant in both major and minor modes were judged more dissonant in a musical context than in isolation. This partly confirms the hypothesis that chords sound more dissonant when heard in an unexpected context than when heard in isolation, since, according to the second hypothesis of Fluidity 1 (the "tonal stability of a chord's function" model), a diminished chord is not expected to sound most consonant when heard on the dominant. However, the second hypothesis of Fluidity 1 also predicts that the tonic will be an unexpected context for both augmented and diminished triads. As such, the fact that both triads were judged to be more consonant when on the tonic than when in isolation does not match the second hypothesis of Fluidity 1, and fails to support the hypothesis that an unexpected context makes chords more dissonant.

This exception of the dominant also may be due to the violation of the role of the dominant. Diminished triads often appear on the dominant in major modes as leading note chords, and are so called because they lead to the tonic to end the cadence. The dominant is, therefore, a familiar harmonic function for the diminished triad. While the diminished triads used in Experiment 2 were built on the fifth note of the scale, a leading note chord occurs on the seventh note of the scale. In order to have worked "properly", the dominant should have led smoothly to the final tonic; but in fact the diminished triads on the fifth note of the scale in the stimuli sequences did not function in this way. These unexpected diminished triads violated the sense of a proper flow from the dominant to the tonic, and hence also violated listeners' expectations – at least, this seems like a reasonable explanation for the perceived dissonance of diminished triads on the dominant. The findings for diminished triads perhaps indicate that harmonic functions only work properly when they are comprised of the right notes of the scale, and they also suggest that participants' C/D judgements are determined more by their familiarity with authentic harmonic progressions than by the mere harmonic function of a particular chord.

The differences between chord types suggest that, as predicted, the influence of context varies according to the chord: in other words, the degree of the fluidity of C/D judgements depends on the type of chord in question. A study by Johnson-Laird, Kang, and Leong (2012) found similar results that the degree to which context influences the listener's judgements of dissonance will vary according to the particular chord being judged. This study compared tonal chords (such as major triads, minor triads, the seventh and the minor seventh) and non-tonal chords (for example, chords that do not consist of the third or fifth), and found that the former were more influenced by context than the latter. However, this result could be attributable to the characteristics of the non-tonal chords: in other words, the acoustic features of these non-tonal chords may have been too original or too different from those of orthodox tonal chords for them to be influenced by context. The qualities and characteristics of chords may contribute to the degree to which context influences the listener. In the case of this present study, the more dissonant or ambiguous the chord was in isolation, the more fluid the C/D judgements of the chord were in musical context. The results of Experiment 1 and the comparison between Experiments 1 and 2 bear this out: augmented triads were judged to be very dissonant in isolation, while diminished triads were judged to be neither particularly consonant nor particularly dissonant - that is to say, diminished triads were ambiguous. In the case of both augmented and diminished triads, their C/D levels fluctuated greatly according to context, especially diminished triads due to their ambiguity. By contrast, major triads were judged to be solidly consonant, whatever their context. Major triads have the clearest root among these four chords, according to Parncutt (1988), and their unambiguousness and stability may have enabled them to maintain their consonant identity regardless of function and context. Support for this assertion comes from Janata (1995), who found that it is more difficult and takes more time to process chords with ambiguous C/D or tonal context than it does to process those that are unambiguous, such as clearly consonant or very dissonant chords.

**C/D and P/U**

With regard to perceptions of P/U, the results reveal a strong correlation between these and C/D perceptions; consonant chords are generally judged to be pleasant, while dissonant chords are typically considered unpleasant. This finding agrees with the notion that C/D and P/U are commonly conflated in people’s minds. However, a few listeners judged neither that consonant chords were pleasant, nor that dissonant chords were unpleasant. Guthrie and Morrill’s (1928) reported incongruency between the perception of C/D and of P/U: they found that musicians judged C/D (measured in terms of fusion and smoothness) and pleasantness differently. The lack of consistency between different studies of C/D and P/U demonstrates that, despite the common assumption to the contrary, P/U and C/D judgements do not always closely match one another. This opens up the possibility for thinking that dissonance can in some instances induce pleasantness in the listener. There are moments in certain pieces of music where dissonant chords in fact sound pleasant, for instance in contexts in which the dissonant chord is resolved in an expected fashion. The pleasantness of certain dissonant chords might be attributable to the fact that, as Meyer (1956) wrote with reference to Zarlino’s view on the matter, dissonance in a piece of music has an aesthetic power that “adds beauty and elegance to the work and makes the consonance which follows more acceptable and sweet” (1956, p. 229). Perhaps more ecologically valid and rich material would be needed to better explore “the pleasantness of dissonance”.

One criticism that might be levelled at this experiment is that the experimental method employed ignores some aspects of tonal music, namely, certain orthodox contexts and resolutions. In Experiment 2, both augmented and diminished triads were made to function in atypical contexts. Some “typical” contexts in which they would normally appear in tonal music were overlooked due to an experimental design that prioritized the influence of function, and it cannot be denied that this increased the likelihood of making these chords more dissonant and unpleasant. This is especially the case for diminished triads on the subdominant, which were judged to be more dissonant in musical context than in isolation. According to expectation theory (Huron, 2006), an unexpected stimulus is liable to induce a negative reaction. It is by no means necessary that a dissonant chord will be an unexpected stimulus, and so expectation theory should not lead us to believe that dissonance will customarily produce a “negative” expectancy reaction: however, unexpected occurrences of augmented and diminished triads in atypical contexts may indeed have led many listeners to respond to the experimental stimuli with surprise, confusion or annoyance. In addition to the problem of augmented and diminished chords appearing in atypical contexts, the experimental design also failed to take into account the fact that these chords are typically supposed to be resolved. It seems plausible that C/D judgements will be influenced by the way in which a chord is resolved in the real listening experience, and so this relation might be a profitable avenue for future research. Recent research shows that expected closures to chord sequences (such as dominant-tonic (V-I)) are judged to have a higher sense of completeness and belongingness within the sequence, less tension, and are more accurately and rapidly judged for consonance (in tune) and dissonance (out of tune) than unexpected closures (Bigand et al., 2003; Bigand et al., 1999; Bigand & Pineau, 1997; Steinbeis, Koelsch & Sloboda, 2006; Tillmann et al., 2008; Tillmann & Lebrun-Guillaud, 2006). In the light of these findings, one can assume that an augmented or diminished chord that is resolved in an expected way will sound more consonant than one with an unexpected resolution. Further studies should help to shed more light both on the importance of orthodox contexts for the perception of augmented and diminished chords, and on the importance of their resolution.

The present study is valuable as it provides empirical data about the influence of musical context on the perceived C/D of major, minor, augmented and diminished triads. The results confirm that the C/D and P/U of chords are influenced by musical context and harmonic function, particularly in the case of diminished triads. The degree to which a chord is influenced by these factors varies according to the type of chord in question, and stands as confirmation of the dual and contradictory character of C/D: its rigidity and fluidity.

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Table 1

*Summary of Fluidity 1 hypotheses.*

| | Hypothesis | | | | | |
|---|---|---|---|---|---|---|
| | Familiarity | | Stability of function | | Position of the fifth | |
| | Augmented | Diminished | Augmented | Diminished | Augmented | Diminished |
| expected /consonant | Tonic Dominant | Dominant | Subdominant Dominant | Subdominant Dominant | Dominant Tonic | Dominant Tonic |
| unexpected /dissonant | Subdominant | Tonic Subdominant | Tonic | Tonic | Subdominant | Subdominant |

Table 2

*The median, 25th and 75th percentiles of C/D judgements of each chord in isolation*

| | 25th percentile | Median | 75th percentile |
|---|---|---|---|
| Major | .687 | .958 | 1.00 |
| Minor | .437 | .708 | .916 |
| Augmented | .000 | .083 | .416 |
| Diminished | .250 | .416 | .729 |

Table 3 *Target chords, harmonic functions and the key of sequences*

| Chord and the root/ Function | G(#/♭) E(♭) **C** | C(#/##) A (#) **F#** | E (#/♭) C (#) **A** | B (♭/♭♭) G (♭) **E ♭** |
|---|---|---|---|---|
| Tonic | C major/minor key | F# major/minor key | A major/minor key | E♭ major/minor key |
| Dominant | F major/minor key | B major/minor key | D major/minor key | A♭ major/minor key |
| Subdominant | G major/minor key | D♭ major/minor key | E major/minor key | B♭ major/minor key |

Table 4. *The significant results of Wilcoxon signed rank test for C/D judgement in isolation (Experiment 1) and in a musical context (Experiment 2).*

| Function/ | | Tonic | | Dominant | | Subdominant | |
|---|---|---|---|---|---|---|---|
| Chord | Mode | z ratio | *p*-value | z ratio | *p*-value | z ratio | *p*-value |
| Aug | Major | **4.84** | **< .001** | -2.87 | .004 | **5.26** | **< .001** |
| | Minor | **5.09** | **< .001** | -2.41 | .016 | **4.76** | **< .001** |
| Dim | Major | **4.49** | **< .001** | **-4.80** | **< .001** | **4.14** | **< .001** |
| | Minor | **4.06** | **< .001** | **-4.61** | **< .001** | **4.70** | **< .001** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Minor | Minor | 2.90 | .004 | 2.23 | .026 | **3.29** | **.001** |

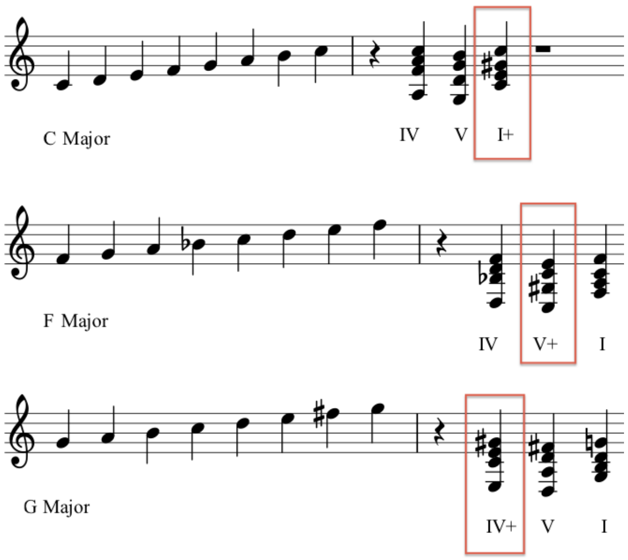


*Figure 1*. Stimuli sequence for Experiment 2.

The chords in boxes are the target chords. All four types of target chord (major, minor, augmented and diminished triads) were allocated a different position in the sequence IV-V-I. The harmonic function of the target chord and the key of the sequence vary depending on the target chord's position.

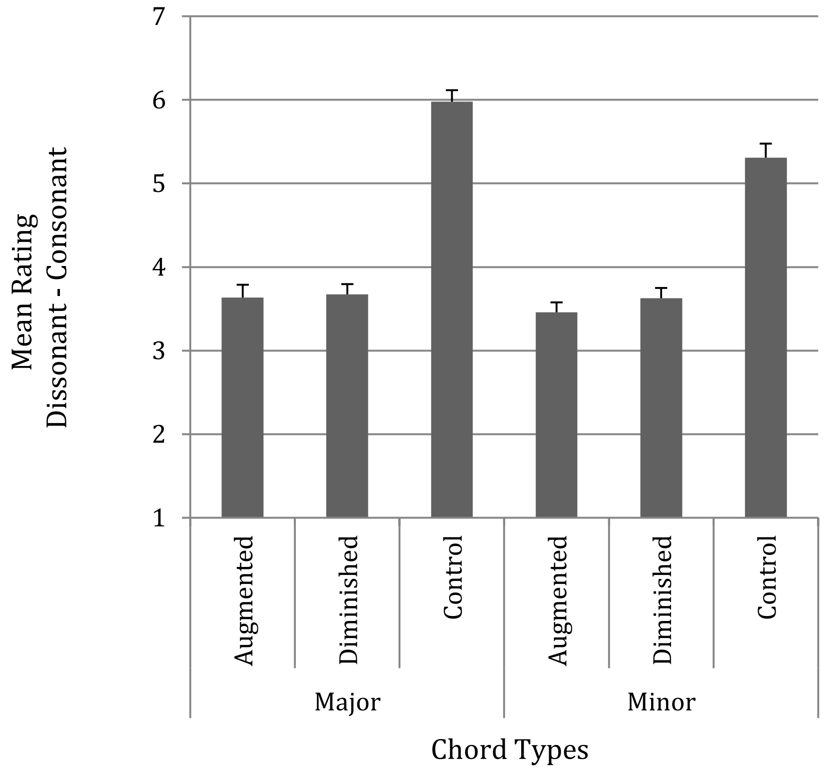


*Figure 2*. Mean ratings of overall C/D judgements for Mode and Chord Type.

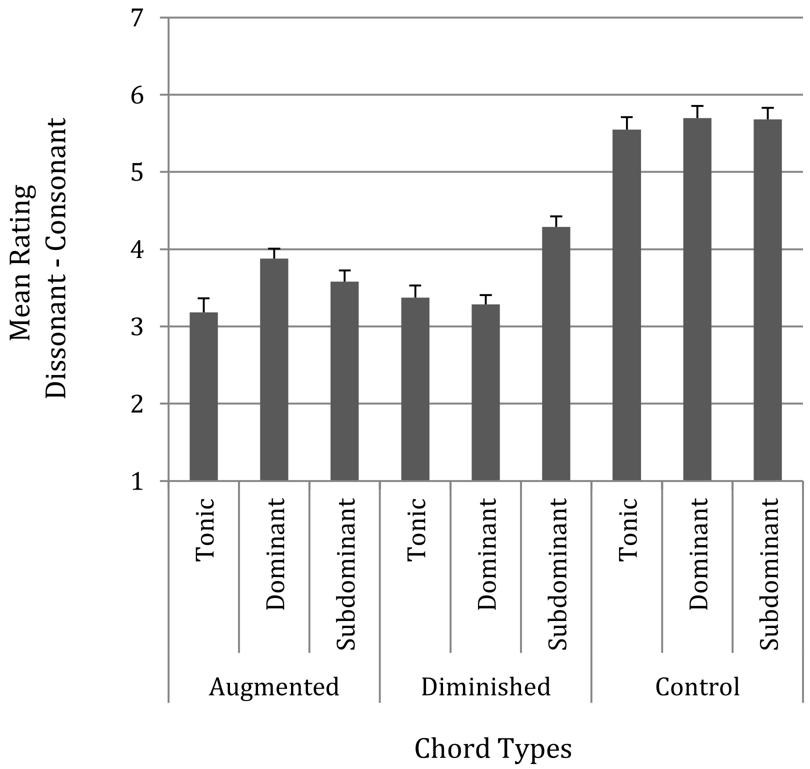


*Figure 3*. Mean ratings of overall C/D judgements for Chord Type and Function

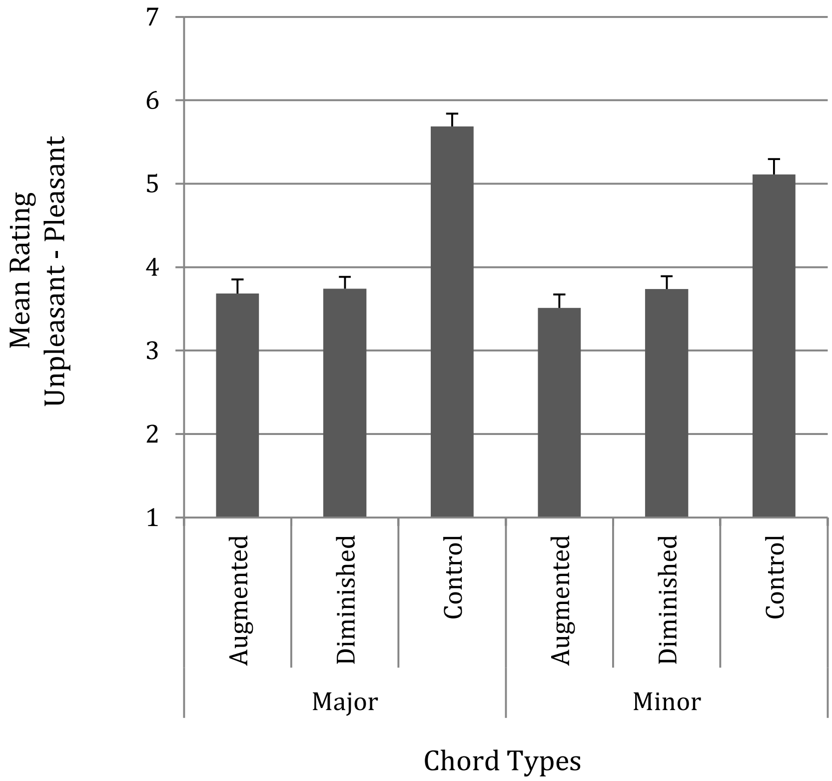


*Figure 4*. Mean ratings for overall pleasantness of Mode and Function

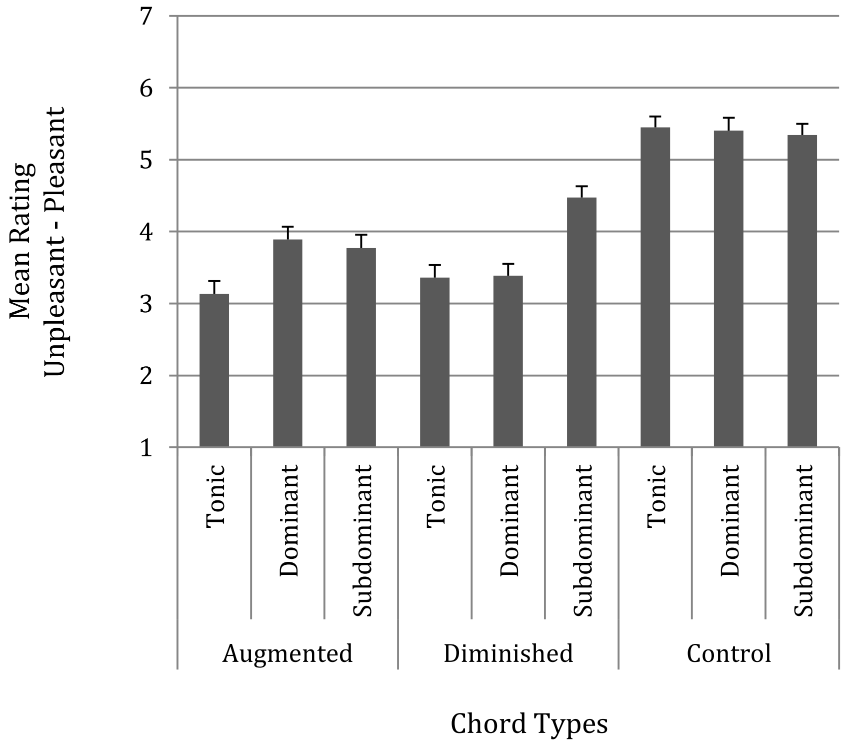


*Figure 5*. Mean ratings for overall pleasantness of Chord Type and Function