Comparing Musicians and Non-musicians' Expectations in Music and Vision

Short Title: Expectation in Music and Vision

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The role of expectation in music has been of research interest for decades. Expectation mechanisms have also received considerable attention in vision, due in part to the widespread interest in predictive coding. Past research has uncovered different types of expectations that may be formed when exposed to a sequential stimulus, such as schematic expectation (based on general knowledge) and dynamic expectation (based on properties within the current stimulus). Yet to our knowledge, a direct comparison of the relative contribution of these types of expectation has not been performed within the same subjects through careful manipulation of stimuli, nor has this comparison been made across the musical and visual domains. This listener study aims to uncover the relative influence of dynamic and schematic expectations in musical and visual stimuli, and investigate the role of expertise in forming expectations by testing both musicians and non-musicians. Our findings suggest that musicians are indeed more sensitive than non-musicians to the dynamic and schematic properties of musical stimuli, and they generally produce a wider range of expectedness ratings than non-musicians. Interestingly, musicians also interpret schematic information in the visual condition differently than non-musicians, suggesting that musical training may have influenced their expectation mechanisms more generally.

CCS CONCEPTS • Empirical studies • User studies • Media Arts

Additional Keywords and Phrases: Expectation mechanisms, music cognition, cross-modal comparisons

1 INTRODUCTION

Expectations shape the way individuals interact with their environments. There has been significant research interest in the topic of expectation in both music cognition [e.g., Meyer, 1956; Huron, 2006; Pearce & Wiggins, 2012] and visual perception [e.g., Egner et al., 2010, Pezdek et al., 1989, Summerfield & Egner, 2009]. Expectation is a process of generating predictions about future events, and plays a role in various processes, from perception of the world, to information processing, to guiding movement, to the formation of emotional responses [Huron, 2006].

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Studies conducted on visual perception and expectation are often closely linked to memory. For example, despite the massive capacity of visual long-term memory (VLTM), memory representations are only sufficient when schematic information is required, but are often insufficient when the task requires more detail [Cunningham et al., 2015]. In addition, context-based (schematic) predictions allow for more efficient object recognition, especially when recognition cannot be accomplished quickly due to the object's intrinsic properties [Bar, 2004]. Schematically *inconsistent* items are also better recalled and recognized than items consistent with one's expectations [Pezdek et al., 1989]. In addition to schematic and contextual information, stimulus-specific properties can contribute to the viewer's dynamic expectations about the stimulus at hand. For example, target repetition, which gives rise to dynamic expectations about the unfolding stimulus, is also found to have a powerful influence on the speed and accuracy of target detection [Godwin et al., 2015].

In the domain of music, Meyer [1956] identified that the link between musical structure and the communication of emotion and meaning is the way in which certain musical structures induces perceptual expectations for forthcoming musical events. These expectations in music can vary between musical styles [Krumhansl et al., 2000] and across degrees of musical training and expertise [Krumhansl et al., 2000; Pearce et al., 2010]. In Western tonal music, the hierarchical organisation means that different scale degrees are associated with particular degrees of tonal stability, where generally, prominent degrees (e.g., the tonic and fifth) are more frequent and perceived as more expected, than less prominent degrees (e.g., the leading tone) [Prince & Schmuckler, 2014].

Studies have also examined the role of domain-specific expertise and training by comparing the expectations between musicians and non-musicians. It has been shown that individuals with high levels of domain-specific expertise (i.e., musicians) generate stronger expectations (and less predictive uncertainty) on average than those with low levels of expertise (i.e., non-musicians) using a classical probe-tone paradigm, where probe tones follow a simple key-defining context [Hansen & Pearce, 2014]. Knowledge about the regularities between the associations of notes, chords, and tonalities in the Western tonal system forms the basis of one's schematic musical expectations [Tillmann & Bigand, 2010].

Few studies have directly compared the relative surprise that can result from *dynamic expectations*, which are generated based on repetitions and patterns found during exposure to an unfamiliar musical work [see Huron, 2007], versus *schematic expectations*, which stem from generalised knowledge acquired through prior exposure [Bharucha, 1987]. It is also currently unclear whether the underlying expectation mechanisms are modality-specific or more general.

We hence attempt to explore these questions in the current study. First, we focus on manipulating dynamic and schematic expectation by systematically varying the predictability of artificially constructed stimuli in a within-subjects design. Through doing so, we aim to assess the relative contribution of dynamic expectation and schematic expectation on the expectedness of the final (target) element in a sequence. We also compare between the music and vision in order to better understand the underlying similarities and differences in expectation mechanisms across domains. Finally, we consider the role of domain-specific expertise by exploring the differences in expectation between musicians and non-musicians. We hypothesize that dynamic and schematic information will have independent effects on expectation, and that musical training will be associated with stronger expectation ratings in the auditory, but not the visual, domain.

For those interested in audio & audiovisual applications, it is useful to know what plays the greatest role in shaping our expectations, and whether these mechanisms are similar across the visual and auditory domains. These findings may be applied to the context of audio technology, especially the area of production, to carefully tailor the listener's expectations (including overall experience and emotional responses) to media items they consume.

2 METHOD

2.1 Participants

Our study included a total of 39 participants (20 females, 19 males)[1]. The average age of the participants was 23.03 years (SD = 3.94 years). All participants reported having normal hearing and normal or corrected-to-normal vision.

Two groups of participants were recruited: musicians and non-musicians. Musicians were defined as those who currently play music, and have had 6 or more years of musical experience/training, while non-musicians were defined as those who do not currently play music, and have had less than 2 years of musical training. Musicians reported an average of 12.6 years of musical training and experience (SD = 3.97 yrs) and 3.37 hours of practice per week (SD = 2.45 hours). Non-musicians had little to no musical training, with an average of 0.16 years studying an instrument (SD = 0.50 yrs).

2.2 Stimuli

56 musical stimuli and 56 visual stimuli were used in the experiment. These stimuli were sequences of either monophonic musical tones or a visual element (a red cube moving around a white screen). Each stimulus was 16 elements long, with each element presented for 500ms in succession, resulting in a total stimulus duration of 8 seconds. The stimuli varied in terms of Dynamic Expectedness, Schematic Expectedness, and whether the final element (the target) was Probable or Improbable based on the previous context (see subsections below for details). In both music and vision, eight distinct stimuli were presented for every combination of factors. These stimuli were created by the first author specifically for the study and were unfamiliar to the participants.

2.2.1 Dynamic Expectation

In both modalities, the amount of Repetition in each sequence was manipulated in order to create stimuli with low or high Dynamic Expectedness (DE). Patterns of 4 notes (for the musical stimuli) or 4 locations of an object (for the visual stimuli) were either Repeated (R) exactly (no transpositions, etc, were used), producing High Dynamic Expectedness, or Non-repeated (NR), producing Low Dynamic Expectedness.

2.2.2 Schematic Expectation

In the musical stimuli, Mode was manipulated such that the stimuli were either composed from a Diatonic scale (D), affording High Schematic Expectedness (SE), or a Chromatic scale (Ch), generating Low Schematic Expectedness. In the visual stimuli, Movement was manipulated such that the cubes were either presented in Sequential locations (SL) around the screen, producing High Schematic Expectedness, or in Randomized (non-sequential) locations (RL), generating Low Schematic Expectedness. An overview of how these manipulations were used to vary Schematic Expectedness is presented in Table 1.

Table 1: Schematic Expectedness for musical and visual stimuli

Stimulus Domain	**Manipulation**	**High Schematic Expectedness**	**Low Schematic Expectedness**
Music	Mode	Diatonic Scale (D)	Chromatic Scale (Ch)
Vision	Movement	Sequential Locations (SL)	Randomized Locations (RL)

[1] An a priori power analysis was conducted using G*Power [Faul, Erdfelder, Lang, & Buchner, 2007] for a repeated measures ANOVA (within-between interaction) to determine the minimum sample size needed. To achieve 0.80 power for detecting a medium effect size (0.5) with $\alpha = .05$ and 2 groups, a sample size of at least 12 would be required.

2.2.3 Probable vs. Improbable Target

The Target, or final event in the sequence, could either be a Probable Target (PT), an expected target that fulfilled all dynamic and/or schematic expectations set up by the preceding context, or an Improbable Target (IT), an unexpected target that violated any dynamic and/or schematic expectations set up by the preceding context. The Improbable Target violates dynamic expectations set up by Repetition in the preceding context, and violates schematic expectations produced either by diatonicity in music (e.g., the target is a non-diatonic tone), or sequential movement in vision (e.g., the target occurs in a non-sequential location). Note that there is no Probable Target for Non-repeated Chromatic stimuli or Non-repeated Random-movement stimuli, as these are instances where the context does not afford any dynamic or schematic expectation to be established, hence there can be no expected or probable target.

2.3 Procedure

At the beginning of the experiment, the study and procedure were explained to the participant, and then the participant provided informed consent. During the experiment, the participant sat at a desktop computer in a quiet laboratory room. The visual and musical stimuli were presented in separate blocks, and the order of blocks was randomized across participants. The musical stimuli played at a comfortable loudness level over headphones (participants were able to adjust the loudness during the practice trials). No sound was played during the visual trials.

On every trial, the participant provided two ratings after the stimulus was presented. First, the participant rated the Expectedness of the final (target) element of the sequence on a discrete scale from 1 (very unexpected) to 5 (very expected). The participant was asked to judge how expected the target element (either a tone or the location of a cube) was given the prior context of the sequence. Then the participant rated the *strength* of his/her expectation on a scale from 1 (weak expectation) to 3 (strong expectation). For this second rating, the participant was asked to rate the strength of their expectation for the final element, given the prior context provided in the trial. Due to space constraints, in this paper we will focus solely on the former ratings (Expectedness of the target).

After the experimental trials, a brief questionnaire was given to the participant to collect demographic information and basic information about his/her musical background (e.g., number of years of formal musical training). In total, the study lasted approximately 40 minutes in duration, and participants were compensated S$6 (approx. £3.18 GBP) for their time.

3 RESULTS AND DISCUSSION

3.1 Music Results

A mixed design (Dynamic Expectedness x Schematic Expectedness x Target likelihood x Musical Background) analysis of variance (ANOVA) was performed for the musical trials, with Group (musicians and non-musicians) as the between-subjects variable, and Expectedness Ratings as the dependent variable. The ANOVA yielded significant main effects of Dynamic Expectedness, $F(1, 2170) = 12.81$, $p < .001$; of Schematic Expectedness, $F(1, 2170) = 87.87$, $p < .001$; of Target likelihood, $F(1, 2170) = 2466.06$, $p < .001$; and of Group, $F(1, 2170) = 16.83$, $p < .001$.

There were also six significant two-way interactions between the variables, which clarify the main effects. First, the interaction between Dynamic Expectedness and Schematic Expectedness was significant, $F(1, 2170) = 39.58$, $p < .001$. Further, significant interactions were found between Dynamic Expectedness and Target likelihood, $F(1, 2170) = 151.10$, $p < .001$, as well as Schematic expectedness and Target likelihood, $F(1, 2170) = 9.91$, $p < .005$. There were also significant interactions between Group and Dynamic Expectedness, $F(1, 2170) = 79.91$, $p < .001$, Group and Schematic expectedness, $F(1, 2170) = 16.98$, $p < .001$, and lastly, Group and Target likelihood, $F(1, 2170) = 107.22$, $p < .001$.

Finally, there were also three significant three-way interactions. The interaction between Group, Dynamic Expectedness, and Schematic Expectedness was significant, $F(1, 2170) = 36.38$, $p < .001$. In addition, there were significant interactions between Group, Dynamic Expectedness, and Target likelihood, $F(1, 2170) = 13.90$, $p < .001$, as well as Group, Schematic expectedness, and Target likelihood, $F(1, 2170) = 3.91$, $p < .05$. Note that it was not possible to test the three-way interaction between DE, SE, and Target Likelihood due to lost degrees of freedom. These effects and interactions for the musical stimuli, shown in Figure 1, will now be discussed.

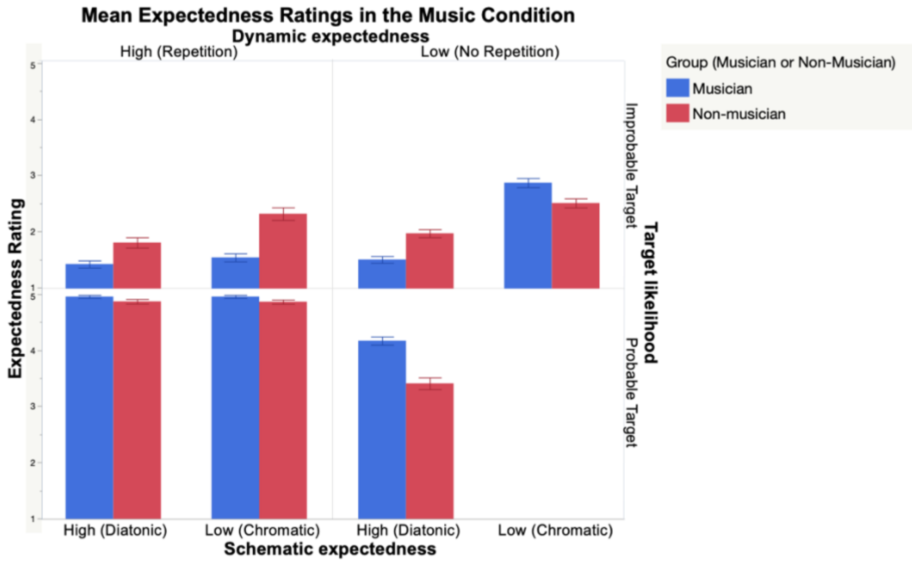

Figure 1: Mean Expectedness Ratings for musicians and non-musicians across music stimuli (error bars represent standard error).

As shown in the bottom-left quadrant of Figure 1, stimuli with high Dynamic Expectedness and a Probable Target garnered very high Expectedness Ratings from both musicians and non-musicians, reaching an almost ceiling effect, regardless of Schematic Expectedness. On the contrary, stimuli with high DE but an Improbable Target yielded lower Expectedness Ratings for musicians than non-musicians, as seen from the top left quadrant of Figure 1. These results suggest that musicians were more surprised by the improbable target than non-musicians, likely because they formed stronger expectations than non-musicians, which were subsequently violated by the IT. Additionally, when the stimuli contained high DE and low SE, non-musicians gave higher Expectedness Ratings than musicians to an IT, further suggesting that non-musicians were less surprised by an Improbable Target when the musical stimuli were chromatic, despite the highly repetitive context.

The results in the bottom-right quadrant of Figure 1 show that Probable Targets in stimuli with high SE but low DE still yield relatively high Expectedness Ratings, with higher ratings from musicians compared to non-musicians. These results seem to suggest that musicians are sensitive to not only DE, but also SE: musicians are, to a greater extent than non-musicians, able to utilise the schematic information provided by the diatonic context to form expectations about the tonality, and their expectations are adequately met by the PT. After listening to a non-repetitive sequence of diatonic tones, hearing another diatonic note (a PT) fit well within the realm of their expectations, based on their high Expectedness Ratings (greater than 4 on a scale of 1-5). Non-musicians' ratings fell around the middle of the range, suggesting that their expectations may not have been particularly strong, so probable targets were neither very expected nor unexpected sounding (although they still exhibited surprise from improbable events, but to a lesser extent compared to musicians).

In the top right quadrant of Figure 1, stimuli with low DE, high SE and an IT, the Expectedness Ratings were lower for musicians than non-musicians, suggesting that despite the lack of repetition, musicians were able to form strong expectations given the diatonic context, hence they were more surprised than non-musicians when their expectations were violated by the improbable target. Interestingly, trials with low DE, low SE, and an IT, garnered higher Expectedness Ratings than trials with low DE, *high* SE, and an IT, especially by musicians (whose ratings are in middle of the expectedness scale). Such findings seem to suggest that participants (musicians especially) were able to recognise that the lack of structure (due to low DE and low SE) prevents strong expectations; that is, realizing that their expectations would neither be met nor violated by the target resulted in their Expectedness Ratings falling in the neutral range.

3.2 Visual Results

A mixed design (Dynamic Expectedness x Schematic Expectedness x Target likelihood x Musical Background) analysis of variance (ANOVA) was performed for the visual trials, with Group (Musicians and Non-musicians) as the between-subjects variable, and Expectedness Ratings as the dependent variable. The ANOVA yielded significant main effects of Dynamic Expectedness, $F(1, 2174) = 54.44$, $p < .001$; of Schematic Expectedness, $F(1, 2174) = 24.26$, $p < .001$; of Target likelihood, $F(1, 2174) = 1944.20$, $p < .001$; and of Group, $F(1, 2174) = 38.21$, $p < .001$.

There were also three significant two-way interactions between the variables. First, Dynamic Expectedness interacted with Schematic Expectedness, $F(1, 2174) = 15.45$, $p < .001$. There were also significant interactions between Dynamic Expectedness and Target likelihood, $F(1, 2174) = 655.38$, $p < .001$, as well as Group and Dynamic Expectedness, $F(1, 2174) = 33.31$, $p < .001$. There were no significant three-way interactions; this aligns with our hypothesis that fewer differences would emerge for the visual compared to musical trials for Group. These effects and interactions for the visual stimuli, shown in Figure 2, are discussed below.

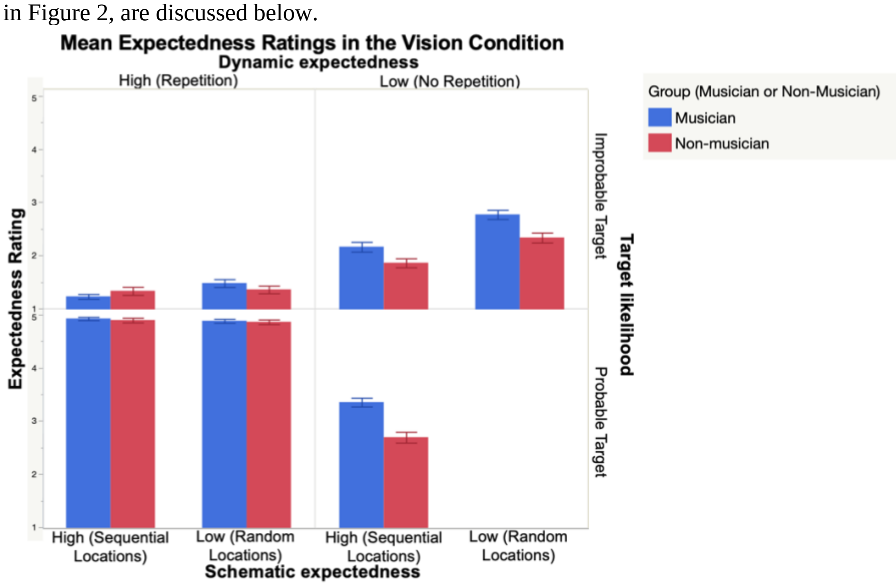

Figure 2: Mean Expectedness Ratings for musicians and non-musicians across visual stimuli (error bars represent standard error).

As shown in the bottom left quadrant of Figure 2, and similar to the music condition, trials with high DE and a PT resulted in very high (nearly ceiling) Expectedness Ratings, for both musicians and non-musicians, regardless of SE. The top left quadrant of Figure 2 shows the opposite effect – here, trials with high DE but an *Improbable* Target resulted in very low Expectedness Ratings from both musicians and non-musicians, regardless of SE. These results suggest that when Dynamic Expectedness is high in vision, both musicians and non-musicians form strong expectations about the unfolding stimulus, resulting in their expectations for the target either being strongly upheld or strongly violated.

As shown in the bottom right quadrant of Figure 2, trials with low DE and high SE produced moderate Expectedness Ratings for PTs, with musicians giving higher Expectedness Ratings than non-musicians. This may suggest that, like the music trials, musicians form stronger expectations than non-musicians when there is schematic information available and a PT, even when DE is low. That said, trials with low DE and an IT (shown in the top right quadrant of Figure 2) also garnered higher Expectedness Ratings (less surprise) from musicians than non-musicians, suggesting that when no repetition was present in the context, musicians formed less distinctive expectations about the target. It is not clear whether this pattern of results (of higher Expectedness Ratings from musicians compared to non-musicians for low DE stimuli) stems from musicians' training in some way, or is due to another factor – more research is needed.

4 CONCLUSION AND FUTURE RESEARCH

In this study, we explored the influence of dynamic and schematic expectations across the musical and visual domains, and investigated the role of expertise in forming expectations by comparing between musicians and non-musicians. As expected, we found that musical training has a greater effect on expectations in music versus vision, which was especially apparent in high DE trials, as discussed below.

In the music condition, contexts with high DE (regardless of SE) led musicians to produce more extreme expectedness ratings of probable and improbable targets than non-musicians. In trials with low DE and high SE, musicians also provided higher expectedness ratings for a probable target, and lower expectedness ratings for an improbable target, as compared to non-musicians. This finding indicates that despite the lack of repetition, musicians were still able to form relatively strong expectations (unlike non-musicians) based on the schematic (diatonic) information present, and were hence more surprised when their expectations were violated by an improbable target. In contrast, musicians (and to a lesser extent non-musicians) seem to recognize that trials with low DE and low SE have little musical structure, and hence do not afford strong expectations. Here musicians provided Expectedness Ratings in the neutral range, which suggests they were less surprised by an improbable target than non-musicians. The differences observed between musicians and non-musicians in the music condition are likely the result of musical training. Given their extensive knowledge and experience of music, musicians have a better understanding of musical structure, and more experience forming expectations of music due to their robust, internalised mental representations of music. In this study, musicians were more sensitive than non-musicians to the types of structure present in the music, and were able to flexibly adjust their expectations based on the context.

These findings are in contrast with the visual condition, in which musicians and non-musicians did not differ in their Expectedness Ratings for trials with high DE (regardless of SE), providing evidence that their expectations (or surprise) of the target were similar for this context. Musicians did, however, differ from non-musicians for trials with low dynamic expectedness: when the visual context was non-repetitive (low DE), musicians provided higher Expectedness Ratings than non-musicians – while they found PTs more expected than non-musicians, they were also less surprised by the improbable visual target than non-musicians. This may suggest that either the musicians' training has played a role in shaping their expectation mechanisms in the visual domain, as musicians generally seem to be more sensitive than non-musicians to the presence or lack of repetition (high vs low DE), or that the non-musicians were actually more sensitive than musicians in differentiating improbable targets in the visual condition. Further research is needed to clarify this finding.

Overall, when provided with a distinct, high DE context, both musicians' and non-musicians' Expectedness Ratings were at the extremes of the response range when their expectations were met or violated. In both conditions, when little structure was present (low DE and low SE), strong expectations could not be formed. Musicians in particular provided ratings that were in middle of the expectedness range, indicating that they were less surprised by an improbable target compared to non-musicians.

A potential limitation of our study is that the schematic context in the visual stimuli may not be a perfect analogue of that of the music stimuli. While the schematic context is clearly established in the musical domain through the use of a diatonic or chromatic scale, the schematic context in vision was provided by modifying the type of movement of the visual object, through the use of sequential or random locations. Whether the schematic context is truly analogous between the music and visual stimuli hence warrants further investigation. Nevertheless, we have obtained promising results that provide valuable insight in the field of expectation across these two modalities. The results show that positive effects of musical training on dynamic and schematic expectation are primarily shown in the auditory domain, with either limited or no transfer to the visual modality. In addition, we believe our findings are of interest when considering applications across audio and video media types. For example, listener's expectations may be customised in order to enhance and sustain their interest in the media items they consume, and this can be tailored for listeners with differing degrees of musical expertise. In the future, we aim to collect more data, and explore how schematic expectedness may be made even more pronounced in the visual stimuli (to be more akin to SE in music).

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