The First International Conference

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# PROCEEDINGS

Editors
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Faculty of Music, University of Arts in Belgrade

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# The Influences of Chord Progression Probability, Predictive Processing, and the Behavioral Inhibition System on Aesthetic Appreciation of Pop Songs

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## Abstract

The precision of prediction errors respectively the relation between the prediction model's parameters (estimated values) and the observed values determines the amount of incongruence or perceived psychological entropy. The following studies attempt to operationalize perceived psychological entropy of musical stimuli on a harmonic level by the probability of occurrence of chord progressions in popular music as well as link predictive processing abilities to inhibition and approach behavior by integrating those parameters into a regression model for preference in relation to perceived psychological entropy (prediction error precision). Based on analyses of thousands of pop songs progression probability was calculated as the conditional probability of each scale-step following the one before in up to four chords in a row. Twenty-eight different stimuli were composed based on progressions with 9 different probabilities, whereby the harmony was the independent variable and tempo, dynamics, instrumentation and voicing were held constant. To investigate the influence of sound, the stimuli were arranged in three different sound settings. Participants were asked to rate the stimuli according to their aesthetic appreciation as well as familiarity and complexity. They also were asked to describe their experiences and personalities regarding sensation seeking, openness, extraversion, predictive processing impairment, BIS/BAS, and music education. According to prominent models regarding arousal potential, approach behavior and preference by Berlyne and DeYoung, an inverted-U relation could be found between the preference for a progression and its perceived psychological entropy. Regression analyses indicate that preference can be predicted by an interaction of psychological entropy index, BIS/BAS and predictive processing abilities.

## Introduction

The inherent logic in harmonic progressions and the development of compositional principles over the past centuries shape our expectation of musical stimuli to a great degree. The balance between prototypical and unpredictable musical events seems to create an optimally challenging and therefore most pleasurable experience. What sounds like an easy guide to compose the next hit song is actually much more complex: not only the objective prototypicality of a musical piece influences the aesthetic judgment but also the recipient's individual experiences in relation to the music.

So it has been reported that music graduate students preferred more atypical chord progressions, whereas musical novices preferred the relative harmonic prototype (Smith & Melara, 1990). This can be explained by a prominent theory about the optimal arousal potential, which a stimulus or situation provides. This theory states that preference – and thus approach behavior – is at its maximum level if the arousal potential is optimal for the individual's cognitive processing capacities (Berlyne, 1974). In accordance with this, arousal potential respectively perceived psychological entropy is determined by accessible information (experience) and leads to different kinds of exploration behavior: either reinforcement learning or approach behavior (DeYoung, 2013). The aesthetic evaluation depends on this relation, accordingly. In terms of cognitive fluency and liking, this theory resolves not only how complexity can explain variances in liking (North & Hargreaves, 2001), but also supports the prominent inverted-U model of preference (Chmiel & Schubert, 2017). This complex relation between an individual and the situation or stimulus, weighing all the present factors as well as experiences against each other to determine the amount of perceived psychological entropy to decide, which kind of exploration behavior will be most rewarding (reinforcement learning through diverse exploration or gain of information through specific exploration) is not only strongly related to behavioral inhibition and approach systems, but also the theory of predictive processing. Thus, both of these traits will be integrated into a regression model of preference for musical stimuli with different amounts of perceived psychological entropy.

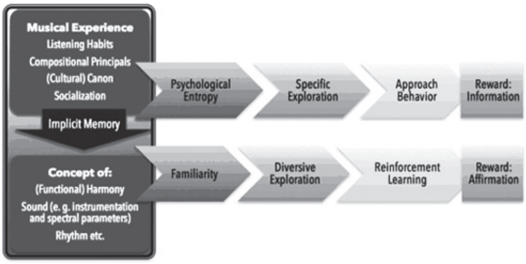

**Figure 1. Model of musical experience influencing prediction models about musical stimuli, which can result in two different kinds of rewarding approach, depending on the amount of perceived psychological entropy.**

As a tool to operationalize musical entropy, the probability of each harmonic scale-step following another was calculated based on a statistical analysis of thousands of pop songs. Two studies were conducted, the first one to evaluate the applicability of chord progressions as an objective indication of perceived entropy and whether or not correlations between aesthetic appreciation of music and the probability of its harmonic progressions can be observed, the second one to integrate BIS/BAS (Carver & White, 2013) as well as predictive processing abilities into an regression model for confirming coherent predictors for preference, independent of chord progression probabilities.

Both experiments will be presented below.

## Method

### First Study

**Stimuli.** Fifteen musical stimuli were composed (5 different probabilities in 3 sound settings), each of them containing 11 bars with 120bpm, the first bar introducing the dominant seventh chord and leading into 8 bars of chorus, followed by 2 bars of tonic fade-out. Each chorus was defined by a one-time repeated progression of four chords as the only altered variable. For example, the functional harmonic description of the stimulus with the highest probability would be $V^7$-I-V-vi-IV-I-V-vi-IV-I-I.

The different sound settings were labeled 'Rock', 'Pop', and 'EDM'. For each sound setting, instrumentation, dynamics, tempo, etc. were held constant, so harmony would be the only altered variable.

**Participants.** Participants ($N$ = 73, $M$[age] = 26.36; $SD$ = 10.86) were asked to rate the stimuli according to their aesthetic appreciation as well as i. a. familiarity, complexity, and innovativeness. They also were asked to describe their musical abilities and experiences and personalities regarding sensation seeking (BSSS; Hoyle, Stephenson, Palmgreen, Lorch, & Donohew, 2002) as well as openness and extraversion (TIPI; Gosling, Rentfrow, & Swann, 2003).

### Second Study

**Stimuli.** The 'EDM' sound setting from study one was used in addition to a newly created second sound setting with similarly artificial sounds, but less percussiveness and inharmonicity. For both settings, 9 Stimuli were composed (in the same manner as in study one) to create a greater variety of progression probability.

**Participants.** Participants ($N$ = 73, $M$[age] = 32.36; $SD$ = 11.85; 32 of whom with a diagnosis of autism spectrum condition) were asked to rate the stimuli regarding aesthetic appreciation as well as liking, familiarity, and complexity. They were also asked to describe their musical background as well as experiences and behavior regarding predictive processing (IPPI) and on the BIS/BAS scale (Carver & White, 2013).

## Results

### First Study

First of all, there were no general significant correlations between liking and measured personality traits (sensation seeking, openness, extraversion) to be found.

In general, an inverted-U correlation could be observed between preference and perceived psychological entropy ($R^2 = .649$, $p < .001$). The psychological entropy index (PEI) was calculated as the product of a priori calculated progression probability and ratings of complexity as well as the sound setting, which was taken into account as a constant.

Differences between the sound settings could be observed for every progression but the most probable one. Significant, but small effects, have been shown by *t*-tests for the 3rd probable progression, which was preferred in Pop ($p = .027$), and the 5th probable progression, which was preferred in EDM ($p = .037$). A medium effect could be found for the 4th probable progression, which was preferred in EDM ($p < .001$).

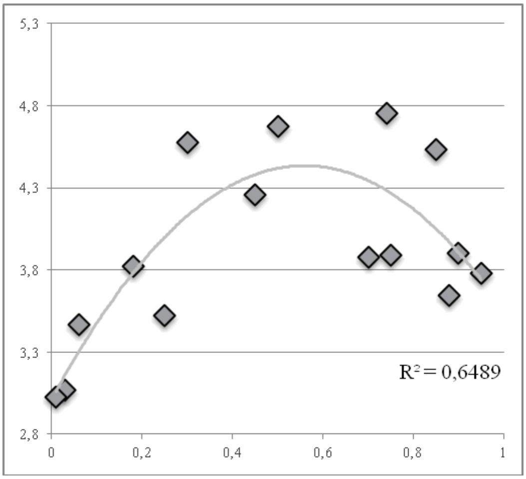

**Figure 2. Regression model of psychological entropy index (PEI; x-axis) and preference rating (y-axis).**

Regression analyses revealed an interaction of familiarity and coherence to be the best predictor for liking the 2nd probable progression in EDM ($t = 2.491$, $p = .017$), and in Pop an interaction of familiarity and complexity ($t = 2.559$, $p = .014$).

For the liking of the 5th progression, there was no satisfying regression model to be found. Although, in EDM the variance in liking could be explained by musical experience ($F = 7.589$, $p < .01$).

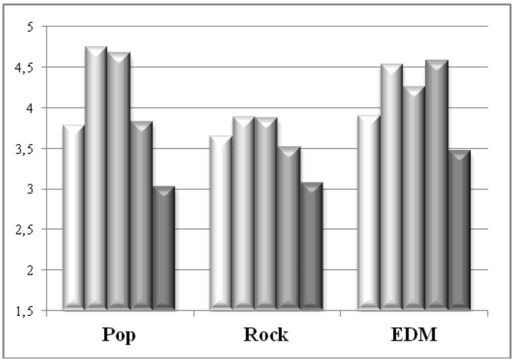

**Figure 3. Preference sorted by progression probability (from most probable to least probable) in each of the 3 sound settings.**

### Second Study

Between the 41 neurotypical and the 32 individuals on the autism spectrum, significant differences could be observed. Participants with ASC described higher behavioral inhibition ($t = 2.082$, $p = .041$) and lower behavioral approach in each dimension (fun seeking: $t = 7.168$, $p < .001$; reward responsiveness: $t = 3.159$, $p = .002$; BAS drive: $t = 2.231$, $p = .029$). Furthermore, a significantly higher predictive processing impairment could be observed in participants on the autism spectrum ($t = 10.00$, $p < .001$, $d = 2.359$). Regarding aesthetic evaluation, individuals with a high degree of predictive processing impairment interestingly rated the stimuli to be lower in complexity, but also expressed less preference in general.

To optimize the parameter weighing of the PEI, this time it was calculated as the product of a priori estimated progression probability and ratings of complexity and familiarity. The inverted-U correlation could again be observed between preference and perceived psychological entropy ($R^2 = .551$, $p < .001$).

Regression analyses revealed consistent interactions between predictive processing impairment, BIS/BAS and perceived psychological entropy as predictors for preference as follows.

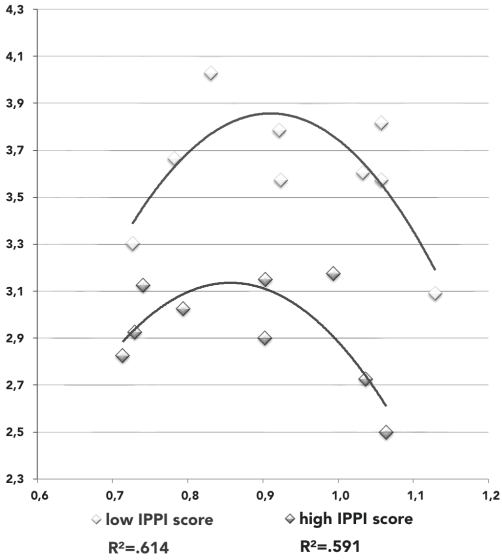

**Figure 4. Regression model of PEI (x-axis) and preference rating (y-axis), showing individuals with high IPPI score (high predictive processing impairment) experiencing more entropy but also having a higher degree of preference for the stimuli in general.**

**Table 1. Regression models to predict preference.**

| **Bayesian regression models of preference for each progression, sorted by mean PEI** | | | | |
|---|---|---|---|---|
| **St.** | ***M* [PEI]** | **Best Predictors** | **$\mathrm{BF}_{10}$** | **$R^2$** |
| **03** | 0.728 | BIS * IPPI * PEI | 1503.806 | .303 |
| **01** | 0.744 | BIS * IPPI * PEI | 447.517 | .276 |
| **02** | 0.781 | BAS-R * PEI | 1055.183 | .265 |
| **04** | 0.851 | *None* | - | - |
| **05** | 0.912 | BIS * IPPI * PEI | 37.055 | .214 |
| **06** | 0.972 | BAS-R * PEI | 16.204 | .161 |
| **08** | 1.021 | BAS-F * BIS * PEI | 361.285 | .271 |
| **07** | 1.034 | BIS * IPPI * PEI | 46.472 | .220 |
| **09** | 1.093 | BIS * IPPI * PEI | 64.603 | .228 |

BIS: Behavioral Inhibition System
BAS-R: Behavioral Approach System – Reward Responsiveness
BAS-F: Behavioral Approach System – Fun Seeking
PEI: Psychological Entropy Index
IPPI: Introspective Predictive Processing Inventory (measuring degree of PP impairment)

## Conclusion

In the first study, the differences per sound setting suggest that sound influences the perception of harmony. The "unusual progression" being the most preferred one amongst the stimuli with the most current sound design from study one suggests that the familiarity of the sound compensates the entropy of the progression, leading to a more tolerable arousal potential.

Additionally, there could be a mere exposure effect responsible for the strong liking of the 2nd progression in 'EDM' since this combination sounded very similar to recent summer hits.

In the second study, with predictive processing impairment, as well as behavioral inhibition and approach, being taken into account, the regression models for preference were much more consistent and coherent. These results suggest that high precision in predictive processing impairment leads to insufficient compensation of entropy, reinforcing BIS and thus decreasing preference.

Additionally, of all the stimuli those had the highest rating in "diverse evaluation" (affective/objective liking; MIAU-2D, Roos, 2019) for which BAS was part of the regression model. Further research is needed to investigate this relation since it is counterintuitive to the theory of BAS leading to greater involvement ("specific evaluation") motivated by seeking a reward in a gain of information by unfamiliar stimuli. However, it could be hypothesized that BAS does motivate both kinds of exploration, which makes it much more interesting than "fun seeking" is involved in the preference for a chord progression with low probability, whereas "reward responsiveness" might be responsible for exploration that leads to reinforcement learning.

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