ON THE IMPACT OF MUSIC ON DECISION MAKING IN COOPERATIVE TASKS

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ABSTRACT

Numerous studies have demonstrated that mood affects emotional and cognitive processing. Previous work has established that music-induced mood can measurably alter people's behavior in different contexts. However, the nature of how decision-making is affected by music in social settings hasn't been sufficiently explored. The goal of this study is to examine which aspects of people's decision making in inter-social tasks are affected when exposed to music. For this purpose, we devised an experiment in which people drove a simulated car through an intersection while listening to music. The intersection was not empty, as another simulated vehicle, controlled autonomously, was also crossing the intersection in a different direction. Our results indicate that music indeed alters people's behavior with respect to this social task. To further understand the correspondence between auditory features and decision making, we have also studied how individual aspects of music affected response patterns.

1. INTRODUCTION

There is plentiful evidence that one's mood can affect how one processes information in a wide array of contexts and tasks. Previous work has established that positive mood induces a relative preference for positive emotional content and vice versa [6, 14]. Recent work has confirmed this effect is indeed induced by music that is culturally categorized as "happy" vs. "sad", and illustrated how the emotional content of music informs the apriori expectation for the emotional content of verbal stimuli [11]. As for non-emotional and quantitative decision-making, previous work has shown robust effects of loss aversion, whereby participants put more weight on potential losses than potential gains. In a recent study, Liebman et al. presented evidence for the complex impact of music-induced mood on risky decision-making in the context of gambling. They observed an overall improved stimulus processing in participants listening to "happy" music compared to "sad" music, i.e., music-induced positive mood has led to better and faster decision-making overall [12].

Given the complexity and variability of the observed effects of music on decision-making in the context of different tasks, an inevitable question arises - how does music affect more complex tasks? More specifically, how does music affect complex decision-making that involves taking into consideration the agency of other entities? In this paper, we study the impact of music on decision behavior in the context of cooperative tasks, in which a person has to take into account the intentions of another agent when attempting to achieve their own goal. To this end, we design an experiment in which a person must cross a simulated intersection that is simultaneously being crossed by another autonomous agent, controlled by artificial intelligence. Our results indicate different types of music indeed have a differential effect on people's behavior in this setting.

The structure of the paper is as follows. In Section 3 we discuss our experimental design and how data was collected from participants. In Section 4 we present and analyze the results of our behavioral study. In Section 5 we examine more closely how music altered the participants' behavior in more specific contexts. In Section 6, we analyze how individual auditory components correlate with the behavioral patterns observed in our human study. In Section 2 we provide additional context about previous work leading up to this paper. Lastly, in Section 7 we recap our results and discuss them in a broader context.

2. RELATED WORK

Studies that induce mood through listening to happy/sad music have shown mood-congruent bias across a range of tasks. Behen et al. [9] showed participants happy and sad faces while they listened to positively or negatively valenced music and underwent fMRI. Participants rated the happy faces as more happy while listening to positive music, and the fMRI results showed that activation of the superior temporal gyrus was greater when the face and music were congruent with each other. In a study of mood and recall, De l'Etoile [4] found that participants could recall significantly more words when mood was induced (through music) at both encoding and retrieval.

Previous work at the intersection of musicology and cognitive science has also studied the connection between music and emotion. As Krumhansel points out [10], emotion is a fundamental part of music understanding and experience, underlying the process of building tension and expectations. There is neurophysical evidence of music being strongly linked to brain regions linked with emotion and reward [2], and different musical patterns have been shown to have meaningful associations to emotional affectations [15]. Similarly, studies have indicated that mood also affects the perception of music [18]. Not only is emotion a core part of music cognitive processing, it can also have a resounding impact on people's mental state, and aid in recovery, as shown for instance by Zumbansen et al. [19] in the case of people suffering from Brocas aphasia. People regularly use music to alter their moods, and evidence has been presented that music can alter the strength of emotional negativity bias [3]. All this evidence indicates a deep and profound two-way connection between music and emotional perception.

Considering the impact of music on risk-related decision making, previous work has studied the general connection between gambling behavior and ambiance factors including music [5, 8, 17] in an unconstrained casino environment. Additionally, Noseworthy and Finlay have studied the effects of music-induced dissociation and time perception in gambling establishments [13].

Lastly, in the context of music and its impact on cooperation, not much research has been done to quantitatively explore how music impacts the cooperative and adversarial behaviors of participants in social settings. Greitemeyer presented evidence that Exposure to music with prosocial lyrics reduces aggression [7]. From a different perspective entirely, Baron was able to show how environmentally-induced mood helped improve negotiation and decrease adversarial behavior [1]. To the best of our knowledge, this is the first work to study how different types of music differentially affect people's decision-making in the context of tasks involving other agents.

3. EXPERIMENTAL SETUP

In this section we describe the details of the experiment conducted in this study. First, we describe the overall procedure. We proceed to describe the participants, the autonomous car behavior, the music selected for the experiment, and the data collected for analysis.

3.1 Procedure

In this study, participants were given control of a simulated vehicle crossing an intersection. They had three control options - speed forward, go in reverse, and brake. In addition to the human-controlled vehicle, another vehicle, controlled autonomously by an artificial agent, was also crossing the intersection from a different direction. If the two cars collided, they would crash. Participants were instructed to safely cross the intersection without crashing. Participants were also instructed that the autonomous car would generally respect the laws of traffic but cannot be blindly relied upon to drive safely. Each time both vehicles cleared the intersection and reached the end of the screen safely, the trial would end and a new trial would commence (a 2 second pause was introduced between trials). The experiment was divided into 8 blocks of 12 trials (for a total of 96 trials per participant). In each trial the behavior of the blue vehicle was randomized, determining its speed and the amount of time it would wait by default in the intersection if it had arrived to the intersection first. In each block, a different song was played, alternating between positive and negative music across blocks. The order of the songs was counterbalanced across subjects. A 3 second pause before the beginning of each block to make sure the new song had started before a new trial commenced. Each experiment lasted approximately 20 minutes. A snapshot of the experiment is presented in Figure 1.

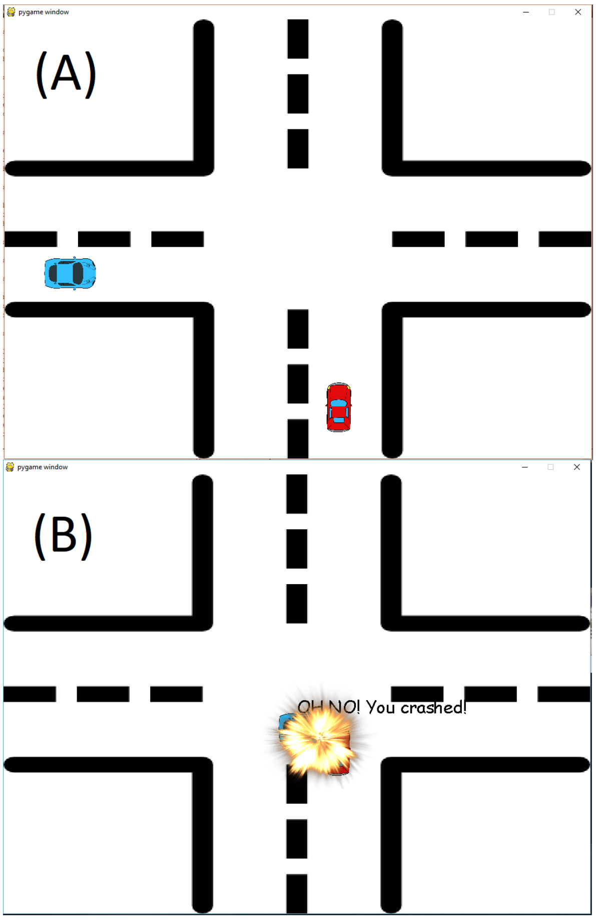

Figure 1. (A) A screen capture of the experiment. The red car was controlled by the participant. The blue car was controlled autonomously. (B) A collision would result in a crash, as demonstrated in this screen capture. After the crash, the trial terminates and the next trial begins.

3.2 Participants

For this paper we have originally collected data from 20 participants. All participants were graduate students who volunteered to participate in the study. Two participants were filtered out for behaving uniformly without paying attention to the experimental conditions (always going forward at the beginning of each trial without slowing, stopping or paying attention to the autonomous vehicle), leaving a total of 18 participants. Note that the comparisons of interest were within participants (happy vs. sad music). Thus, the sample size was sufficient to detect statistically significant differences in behavior between these conditions.

3.3 Autonomous Car Behavior

The key variability in stimuli in this experiment was presented through randomization of the autonomous car behavior. The three main aspects of the autonomous car behavior that were variable were its speed approaching the intersection, how long it would wait in the intersection before going forward if it arrived to the intersection first, and how fast it would move into the intersection and onward after entering the intersection. Participants were instructed not to blindly rely on the autonomous car's behavior, but in the scope of this experiment we opted to have the autonomous car always give right of way if the human-controlled car made it to the intersection first. The consequence of this was that the decision whether to give right of way or move forward was almost always in the hands of the human participant. Indeed, one of the explicit goals of this study were to examine how different music-induced mood would affect people's aggressiveness vs. their inclination to give right of way.

3.4 Music

The music used for this experiment is the same as that used in [11]. It is a collection of 8 publicly available songs which was surveyed to isolate two clear types - music that is characterized by slow tempo, minor keys and somber tones, typical to traditionally "sad" music, and music that has upbeat tempo, major scales and colorful tones, which are traditionally considered to be typical to "happy" music. The principal concern in selecting these musical stimuli, rather than their semantic categorization as either happy or sad, was to curate two separate "pools" of music sequences that were broadly characterized by a similar temperament (described above), and show they produced consistent response patterns. In [11], it has been shown experimentally that the selected music was effective for inducing the appropriate mood. This was done by selecting a separate pool of 40 participants and having them rate each song on a 7-point Likert scale, with 1 indicating negative mood and 7 indicating positive mood. It was then shown that the songs designated as positive received meaningfully and statistically significantly higher scores than those denoted as sad.

4. OVERVIEW OF RESULTS

In this section we survey the key findings of the study, examining the participants' behavior globally (that is, across all types of circumstances and autonomous vehicle behavior).

Figure 2. Normalized minimal distance kept from the autonomous car by the participants in the sad and happy music conditions (here and elsewhere, bars represent std. error). Participants tended to keep a lower minimal distance when listening to sad music.

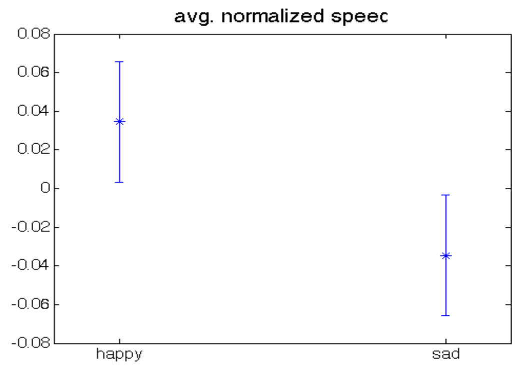

Figure 3. The average normalized speed of the participants in the happy and sad music conditions. Participants were more likely to go faster when listening to happy music.

4.1 Minimal Distance from Autonomous Car

The most statistically significant difference ($p < 0.05$ using a paired t-test) across all trials was that participants listening to sad music kept a lower minimal distance overall from the autonomous car compared to when they were listening to happy music. In other words, their behavior when listening to sad music was riskier and less considerate ("cutting it closer" with respect to how much margin for error they kept when entering the intersection). This result is illustrated in Figure 2.

4.2 Driving Speed

Participants also differed in their driving speed in the sad and happy music conditions (significant at $p < 0.05$ using a paired t-test). Overall, participants were more likely to go fast in the happy music condition compared to the sad music condition, as reflected in Figure 3.

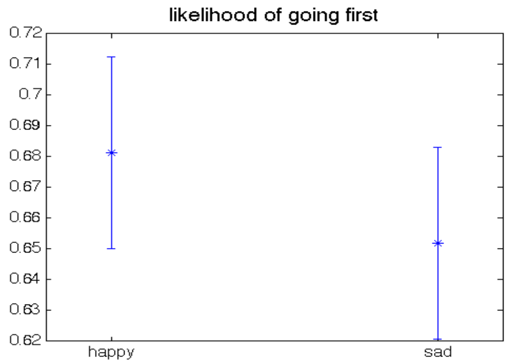

Figure 4. The likelihood of the participants to go first into the intersection in the sad and happy music conditions. Participants were more likely to go first when listening to happy music.

4.3 Right of Way

Another difference, which is strongly related to the previous observation, and is borderline significant [1] (at $p < 0.1$ using a paired t-test) was that participants listening to happy music were more likely to go into the intersection first compared to when they were listening to sad music, as illustrated in Figure 4.

5. BREAKDOWN OF USER BEHAVIOR UNDER DIFFERENT TRIAL CONDITIONS

In this section we consider how different music induced different participant behavior when breaking down the trials by the different types of autonomous car behavior. It is worth noting that the observation made in the previous section held under most partitions of the trial data.

5.1 Behavior under Different Autonomous Car Intersection Wait Times

If we compare how participants behaved when the autonomous vehicle waited $<$ 4 seconds at the intersection, the difference in the participants' driving speed because dramatically more accentuated in the happy vs. sad music conditions. Additionally, the participants' difference in wait times at the intersection in the happy and sad music conditions also becomes more differentiated when we only consider trials in which the autonomous car waited less than $<$ 4 seconds. These observations are presented in figures 5(a) and 5(b), and are both statistically significant with $p < 0.05$ using an unpaired t-test.

[1] A 0.1 threshold for testing the significance of p-values is accepted in the context of relatively small samples sizes. Nonetheless, we strive to use these measures responsibly in our choice of language, thus using the equally common term "borderline significance" to describe results with p-value < 0.1 but > 0.05

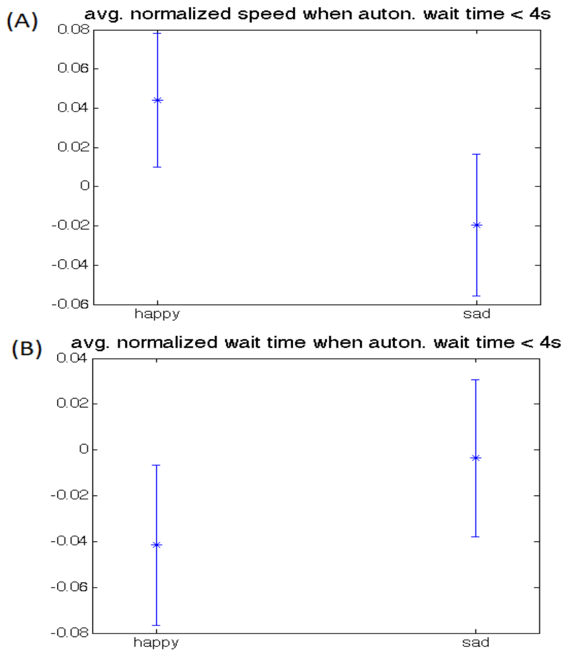

Figure 5. (a) Normalized average per-trial speed of participants in the happy and sad music conditions, specifically in the case that the autonomous vehicle waited less than 4 seconds. (b) Normalized per-trial time waiting at the intersection of participants in the happy and sad music conditions, specifically in the case that the autonomous vehicle waited less than 4 seconds.

5.2 Behavior under Different Autonomous Car Average Speed

A similar related trend to that observed in the previous section were observed when considering the average speed of the autonomous car. In trials in which the average speed of the autonomous vehicle was above the median, people were slower to drive and took longer to wait at the intersection while listening to sad music, compared to when listening to happy music (again with $p < 0.05$ using an unpaired t-test).

6. IMPACT OF MUSICAL PARAMETERS ON USER BEHAVIOR

The partition between "positive" and "negative" mood-inducing songs is easy to understand intuitively, and in itself is enough to induce the different behavioral patterns discussed in the previous section. However, similarly to the analysis performed in [11] and [12], we are interested in finding a deeper connection between the behavior observed in the experiment and the different characteristics of music. More exactly, we are interested in finding the correspondence between various musical features, which also happen to determine how likely a song is to be perceived as happy or sad, and the driving decision-making manifested by participants. To this end, we considered the 8 songs used in this experiment, extracted key characterizing features which we assume are relevant to their mood classification, and examined how they correlate with the subject behavior we observed.

6.1 Extracting Raw Auditory Features

We focused on four major auditory features: a) overall tempo; b) overall “major” vs. “minor” harmonic character (we will refer to this feature as “major chord ratio” for simplicity); c) average amplitude, representing overall loudness; and d) maximum amplitude, representing peak loudness. Features (a), (c) and (d) were computed using the Librosa library [16]. To compute feature (b), we implemented the following procedure, similar to that described in [11]. For each snippet of 20 beats an overall spectrum was computed and individual pitches were extracted. Then, for that snippet, according to the amplitude intensity of each extracted pitch, we identified whether the dominant harmonic was major or minor. The major/minor score was defined to be the proportion of major snippets out of the overall song sequence. Analysis done in [11] confirms these features are indeed associated with our identification as “positive” vs. “negative”. Having labeled “positive” and “negative” as 1 and 0 respectively, a Pearson correlation of $0.7-0.8$ with p-values ≤ 0.05 was observed between these features and the label. Significance was further confirmed by applying an unpaired t-test for each feature for positive vs. negative songs (p-values $< .05$).

6.2 Results

Overall, the most prominently influential aspect of the music as observed by statistical analysis is the loudness of the music. Additional effects were observed relating to tempo and major chord ratio, but they did not meet the same criteria for significance.

6.3 Loudness and Overall Time Out of Intersection

The normalized overall time out of intersection is the total time it took the participant to drive up to the intersection, wait, and cross the intersection, normalized per subject. The normalized time out of the intersection was statistically significantly ($p < 0.05$[2]) inversely correlated with both the average loudness (r = -0.72) and the maximum loudness (r = -0.77) of the music. The correspondence between the average loudness and the overall time out of intersection is presented in Figures 6 (the findings for the maximum loudness are similar). In other words, the louder the music was, the faster people were to complete the task.

6.4 Loudness, Speed, Time Stopped, and Minimal Distance

Loudness also impacted various aspects of participant behavior that are related to the participants’ driving speed and overall aggressiveness. These results are borderline significant at $p < 0.1$ for all correlations reported in this subsection.

[2] P-values for correlation are results obtained by analysis of the distribution of correlation values given the null hypothesis.

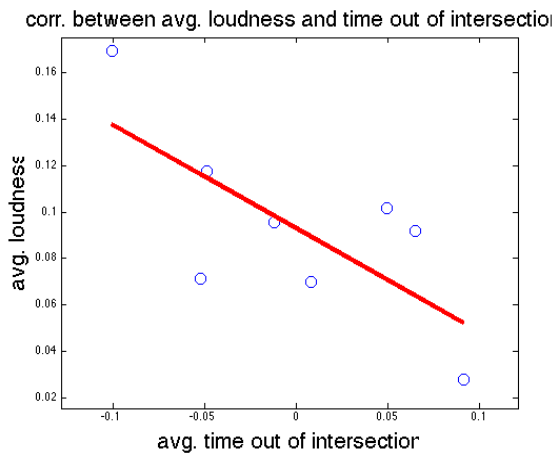

Figure 6. Correlation between the average loudness of the music and the normalized total time out of the intersection for the participants.

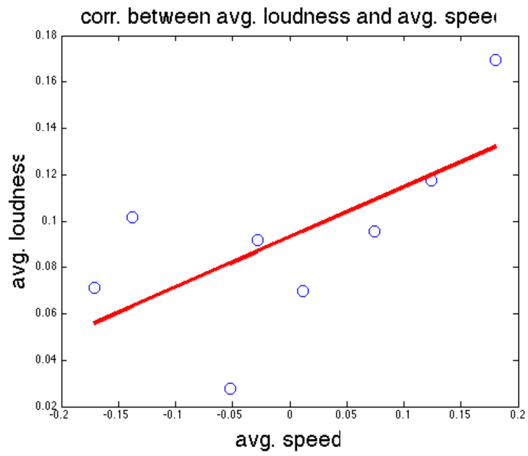

Figure 7. Correlation between the average loudness and the average speed of the participants.

- Most straightforwardly, the average loudness was positively correlated (r = 0.65) with the normalized average speed of the participants, meaning that participants drove faster when listening to louder music. This result is illustrated in Figure 7.
- Similarly, other metrics reflect overall speed, including the minimum speed, the median speed and the initial speed (speed after 1 second from the beginning of the trial) were positively correlated with $r > 0.6$.
- The overall normalized time the participants stopped at the intersection was inversely correlated at r = -0.67 with the average loudness, meaning people were faster to continue into the intersection when listening to louder music. This finding is presented in Figure 8
- Lastly, the minimal distance the participants kept from the autonomous car was positively correlated

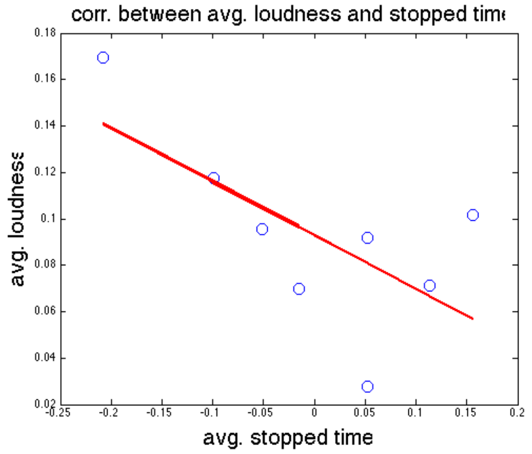

Figure 8. Correlation between the average loudness and the average time the participants stopped at the intersection.

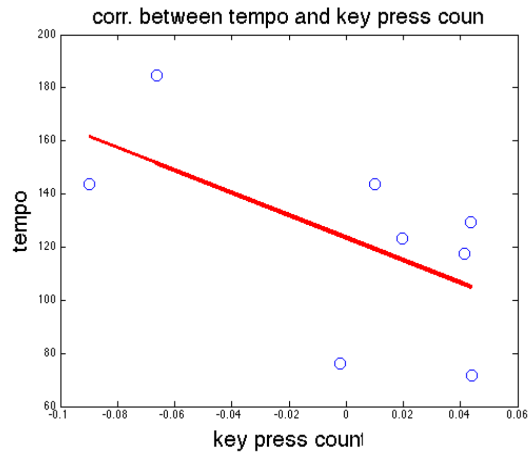

Figure 9. Correlation between the normalized key press count of the participants and the tempo.

with the average loudness, meaning the louder the music was, the higher the minimal distance was. Considering the other findings in this section and the fact that the minimal distance and the average speed are positively correlated at r = 0.75 (and $p < 0.05$), it is reasonable to assume this relationship is a result of the impact of loudness on the participants' speed rather than an indication of how loud music increases people's risk aversion, for instance.

6.5 Tempo and Hesitancy

The total number of key presses per trial, normalized per participant, is a good proxy for hesitancy in decision making (speeding and slowing down, going forward and braking, etc). Interestingly, the key press count was inversely correlated to the tempo (r = -0.59 and $p < 0.1$), suggesting faster music reduced people's hesitancy. This results is presented in Figure 9.

6.6 Additional Observations

Beyond the results reported thus far in this section, several relationships between musical features and participant behavior were observed that did not meet the $p < 0.1$ criterion for significance, but came sufficiently close to merit mention:

- The normalized key press count was also inversely correlated with the major chord ratio (at r = -0.52), implying it's possible that music that leans heavier towards major harmonies also reduces hesitancy in the participants.
- The the major chord ratio was also positively correlated with the maximum speed of the participants, and the minimal distance the participants kept from the autonomous car, at r = 0.54 and r = 0.52, respectively.
- The tempo was positively correlated with both the average and the max speed at r = 0.53 for both.

7. SUMMARY AND DISCUSSION

In this study we analyzed how people's decision-making behavior is affected by music in the context of a social task which requires a certain level of cooperation to avoid adverse consequences. Participants were required to drive a simulated car through an intersection while another car, controlled by an autonomous agent, was also crossing from a different direction. Examining the results reveals a compound picture befitting the subtleties of the performed task. While happy music induced some aspects of behavior that could be described as more social, namely that participants kept a safer distance from the other car when crossing, they also manifested less social behavior by driving faster and being less likely to let the autonomous vehicle go first. All in all, our initial expectation that happier music would make people more cooperative was not supported by the findings. Conversely, it can be argued that sad music made people slower and more cautious, and therefore safer to their environment and to the other agent specifically. This study is the first step towards a better understanding of how music informs people's decision-making in multi-agent environments that require some level of cooperation. Follow-up work would help refine our observations, as well as possibly leverage them in the context of human-agent interaction and negotiation.

8. ACKNOWLEDGMENTS

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