Proceedings of the 12th International Conference on Music Perception and Cognition and the 8th Triennial Conference of the European Society for the Cognitive Sciences of Music, July 23-28, 2012, Thessaloniki, Greece
Cambouropoulos E., Tsougras C., Mavromatis P., Pastiadis K. (Editors)

Music and the Phonological Loop

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ABSTRACT

Research on the phonological loop and music processing remains inconclusive. Some researchers claim that the Baddeley and Hitch Working Memory model (1974) requires another module for music processing while others suggest that music is processed in a similar way to verbal sounds in the phonological loop. The present study tested musical and verbal memory in musicians and non-musicians using an irrelevant sound-style working memory paradigm. It was hypothesized that musicians (MUS –at least seven years musical training) would perform more accurately than non-musicians (NONMUS) on musical but not verbal memory. Verbal memory for both groups was expected to be disrupted by verbal irrelevant sound only. In the music domain, a music expertise x interference type interaction was predicted: MUS were expected to experience no impairment under verbal irrelevant sound whereas NONMUS would be impaired by verbal and musical sounds. A standard forced choice recognition (S/D) task was used to assess memory performance under conditions of verbal, musical and static irrelevant sound, across two experiments. On each trial the irrelevant sound was played in a retention interval between the to-be remembered standard and comparison stimuli. Thirty-one musically proficient and 31 musically non-proficient Belmont University students participated across two experiments with similar interference structures. Results of two-way balanced ANOVAs yielded significant differences between musical participants and non-musical participants, as well as significant differences between interference types for musical stimuli, implying a potential revision of the phonological loop model to include a temporary storage subcomponent devoted to music processing.

I. INTRODUCTION

Recall that the phonological loop is the portion of the working memory model that processes and encodes auditory information (Baddeley & Hitch, 1974). One debate among psychologists and music psychologists centers on the phonological loop and how Baddeley's model treats music. Musicians and researchers debate whether the phonological loop specializes only in language or if other meaningful sounds (such as music) have an elevated meaning over sounds like noise. Salamé and Baddeley (1989) found that participants in word recall tests experienced substantial interference from unattended speech, even in a foreign language, but very little interference from static. Additionally, they tested people in word recall using music, both instrumental and vocal, and found that only the music with words caused substantial interference, though the instrumental music caused slightly more interference than the static. This, they concluded, revealed the phonological loop to be primarily a language processor, with music using the articulatory loop while language could be accessed using the temporary storage component.

Music in working memory, however, seems to carry many similar properties to language in working memory (Williamson, Baddeley, & Hitch, 2010). For example, melodic memory capacity as found by Pembrook (1987) is approximately 7-11 notes, which is related both to capacity for chunked information (Miller, 1956) as well as length-per-item effect on memory (Baddeley, Thomson, & Buchanan, 1975). Similarly to verbal information, if the number of tones in an interference time frame is increased (even if the time is constant), performance decreases; with words, if more words are added but the interference time kept constant, the same effect occurs (Berz, 1995).

In contrast, similar experiments to language interference experiments were conducted with musicians and non-musicians regarding music, and the results suggested another component was needed. Musicians were able to recall tones with minimal interference from language but a great deal of interference with music, while non-musicians experienced equal interference from language and music (Deutsch, 1970; Pechmann & Mohr, 1990; Jones & Macken, 1993). This led music psychologists to question the working memory model as incomplete for data dealing with musical memory.

Psychologists from the music community (Berz, 1995; Deutsch, 1975) state that music may need its own component, or at least may be processed separately from language. Based on interference experiments with digits and pure tones (Williamson, Mitchell, Hitch & Baddeley, 2010; Deutsch, 1970) and suppression experiments with digits and pure tones (Schendel & Palmer, 2007), the current phonological loop description seems incomplete. In studies of the recency effect and modality effect (Roberts, 1986)—which is the advantage of aural presentation over written presentation—found that linking the two resulted in differences between music and language. Additionally, Berz (1995) argues that due to the dissimilarity, Baddeley's model does not fully explain memory in musical listening or differing degrees of interference between language and music, suggesting that "musical information is held in a different area in [working memory] than is verbal information." This has implications for people with working memory deficiencies or damage, because a second process or loop could lead to alternate means of acquiring new information, despite damage to language processes or music processes.

While the debate continues, there exists a middle-ground solution that has yet to be fully tested. This solution is the possibility that the phonological loop processes all sound, but there are additional temporary storage subcomponents within the larger component that applies to each form of sound containing a meaning to the listener, such as musical patterns to musicians or specific birdcalls to ornithologists. But there only need be one loop—one rehearsal process through which all sounds go to be encoded and remembered. Like for language, the additional phonological temporary storage subcomponents provide for long-term memory retrieval for each organized system of sounds meaningful to the listener. This solution could be illustrated through interference experiments, specifically similar experiments to past methods with some modifications.

Previous experiments involving music, language, and interference have contained a few structural flaws regarding music cognition, focusing on pitch memorization versus memory for actual musical phrases (Deutsch, 1970, Pechmann & Mohr, 1992). Many studies have shown that much of musical memory involves pitch relationships rather than just memory for individual pitch (see Levitin, 2006, for review; Cuddy, 1971; Dewitt & Crowder, 1986; White, 1960), thus allowing people to recognize songs in different keys, in different modalities, and songs being sung/played by a wide variety of voices/instruments. Previous music memory experiments relied solely on a participant memorizing a pitch outside of any tonal context and remembering it across several randomly arranged and generated pitches, also without tonal context or center. The addition of random pitches created an atonal environment (or, occasionally and accidentally, a tonal environment in which the original pitch does not fit). These methods make the trials between music and language not equivalent, as English language is always within the context of the English lexicon.

Another problem with previous experiments is a lack of specificity in defining proficient musicians in the trials, sometimes by the admission of the researchers themselves (Pechmann & Mohr, 1992, accepted participants who played an instrument at the time of the experiment as musicians). This lack of definition specificity could be responsible for the varying results between strength of affect between language interference and music interference, as well as the overall interpretation of the data into its implications for working memory. Cuddy and Cohen (1976) found that training affected interval recognition, suggesting that “trained subjects are able to draw on a richer [long-term memory], allowing more efficient LTM strategies to be applied in order to chunk information so that storage can be increased” (Berz, 357). Also, magneticencephalography (MEG) studies reveal that intense musical training and experience modifies the brain to use similar neural processes for musical imagery and perception for superior music processing (Herholz, Lappe, Knief, & Pantev, 2008).

The standardization of “musician” within these experiments would lead to more consistent and revealing results and conclusions. Thus, the definition being used in this study will be supported by research into what defines a musician. Research from the study by Ericsson, Krampe, and Tesch-Römer (1993) in which they investigated hours of practice/years of instruction and level of expertise (professional, best expert, good expert, least accomplished expert, and amateur), provides a clear definition for a musical proficiency that can mirror English speakers’ proficiency for the English language. The resulting definition is as follows: the proficient musician has had at least 7 years of private instruction on an instrument or voice, at least 4 of which were consecutive. Thus, the groups of musician and non-musician will be clearly defined.

There were four major hypotheses for the study, which are as follows:

1) That musically proficient participants (MUS) would not differ from musically non-proficient participants (NONMUS) on the language stimuli.

2) That MUS would perform more accurately than NONMUS on the musical stimuli.

3) That MUS on music stimuli would perform more accurately with static interference and language interference than with music interference.

4) That NONMUS on music stimuli would perform more accurately with static interference than with language interference or music interference.

II. EXPERIMENT 1

Participants experienced a standard/comparison forced choice procedure (Schendel & Palmer, 2007) with target stimuli consisting of either a three-syllable word or three-note phrase. Interference consisted of white noise, language, or music. The type of language and music interference differed between Experiment 1 and Experiment 2. It was unclear whether complete phrases or a list of other words (English and music) would be ecologically valid without introducing confounding variables or diminishing the effect of the interference. Thus, both were tried and the results compared. In this experiment, language interference consisted of complete sentences, and music interference consisted of complete musical phrases. Both were spoken or played to fill 5s without extreme distortion of normal prosody or tempo.

A. Participants

Participants were Belmont University students who learned English as their primary or first language. Each participant was examined for musical proficiency, with MUS having completed private study with an instructor on an instrument or voice for 7 years or more (at least 4 of which were consecutive) (Ericsson et al, 1993). All participants were volunteers, and each participant received a $5 reward for the completion of the study. In Experiment 1, there were a total of 11 MUS (8 men, 3 women), ages 18 to 22 (M=20.09 years, SD=1.45) and 11 NONMUS (3 men, 8 women), ages 18 to 22 with one 50-year-old participant (M=22.81 years, SD=9.10).

B. Design

We used a 2 x 2 x 3 mixed factorial design with the between-group variable being group (MUS or NONMUS) and the within-group variables being stimulus type (language or music) and interference type (static, language, or music). Each participant received all tracks used in the experiment.

C. Materials

There were 36 total audio trials. Eighteen trials used a three-syllable English word to be remembered, and 18 trials used a musical phrase. The English words were randomly selected from a list generated by the MRC Psycholinguistic Database (Coltheart, 1981). Parameters were set to only include three-syllable nouns with a familiarity rating of 100-300, concreteness rating of 100 – 450, and age of acquisition rating of 450 – 699. Of the selected words, half were altered for a "different" comparison stimulus. For the "different" comparison stimuli, syllables were coded into the MRC Psycholinguistic Database to produce a list of words with two of the three syllables matching the target word, and the most similar word was chosen as the comparison stimulus. A female recorded all vocal material using an Audio Technica AT2020 microphone and GarageBand (3.0.5) run on a MacBook using OS X Leopard.

The musical phrases were randomly selected from a list given in Gordon's *Tonal and Rhythm Patterns* (1976) and randomly selected using Random.org (Haahr & Haahr, 2010). The list contained dominant patterns, major sub-dominant patterns, and minor subdominant patterns in the key of C. All patterns were rated as "moderate" according to the text, and patterns of any more or less than three notes were eliminated from random selection. Six patterns of each category were randomly selected, and three patterns of each category were altered for a "different" comparison stimulus. For the "different" comparison stimuli, one pitch was altered up or down a half or whole step in order to maintain melodic contour. The musical phrases and verbal words were matched for length of time to say and hear without denaturing the word (approximately 1.5s). Notes were entered using a MIDI controller in GarageBand, and the instrument setting was the grand piano timbre within GarageBand.

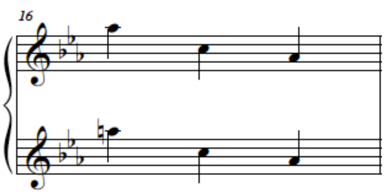

Figure 1: Example of a target musical stimulus (top measure) and a different comparison musical stimulus (bottom measure).

Six trials were used for participant practice and were therefore not analyzed with the 30 test trials for the final data analysis. The practice trials were the same for all participants, and were randomly chosen from the 36 to include one of each condition combination. The 30 experimental trials contained 15 language-stimuli tracks and 15 music-stimuli tracks. Each stimuli type (language and music) contained five tracks with static interference, five tracks with language interference, and five tracks with music interference.

Each trial contained a sine wave attention tone at 523.251 Hz, approximating C5, generated by Audacity (Mazzoni, 2010). The attention tone sounded for 500 ms at the start of the track, followed by a target stimulus (1.5s) and the same stimulus repeated, then interference for 5s, and finally a comparison stimulus (1.5s). A pause of 1s separated each auditory section presented, and a 5s interval was allowed after the presentation of the comparison stimulus for answering. Within the interference, the attention tone was again presented for 1s in order to maintain attention.

The trials were presented through headphones on either a Dell desktop running Windows XP or a MacBook laptop running OS X Leopard. The presentation used Max MSP Runtime and slide images indicating trial number (e.g. "Trial 1 of 30") on either computer. The program routine was written on Max MSP specifically for this study (Volker, 2010).

In Experiment 1, the language interference was one of 12 sentences selected from an online writing blog called A Year in Prose (2010). Sentences were selected for length, imagery (depicting a scene or image), and diversity of word content. The music interference was one of 12 homophonic musical phrases selected from a beginner pianist collection (DeBenedetti, 2010). Phrases were selected from pieces based on note diversity (more rather than fewer), contour (changing contour rather than flat contour), and length.

Event in Track:	C5	"Modernist"	"Modernist"	Interference	"Medalist"
Timeline (in s):		2s	4.5s	7s	13s

Figure 2: Outline of an example trial, with event on the top and the start time of the event on the bottom.

D. Procedure

Before the experiment began, each participant signed an informed consent form, and I announced the trial design and keyboard instructions for providing an answer to each trial. For each attention tone during the interference, participants were instructed to press the spacebar. For each comparison stimulus, participants were instructed to press 1 for "same" or 0 for "different," and then pressed enter to move on to the next trial. Participants were encouraged to answer as soon as possible and not to spend too much time deliberating, but not to sacrifice accuracy for speed. Then, each participant started the program on an individual computer. After entering demographic information (including classification as MUS or NONMUS) and a review slide of the instructions, participants began with the six practice trials, and they were allowed to ask questions and adjust headphone volume during the practice trial phase. After the practice trial phrase, participants received another review slide of the instructions and were allowed to move on to the experimental phase. The program then randomly selected the order of the 30 experimental trials for each participant; therefore, no participant received the same trial order. After all trials, the participants were debriefed on the purpose of the study and expected results, had any remaining questions answered, were rewarded with $5 cash for completion, and then were dismissed.

This experiment's sessions were held in a computer lab using either the Dell desktops or the MacBook, and using various in-ear headphones. Numbers of participants ranged from one to five in a given session, with the average being one participant, and there were 10 sessions total. Each session lasted between 25 and 35 minutes.

E. Results

A two-way balanced-design ANOVA was used to analyze accuracy for each stimulus type (language stimuli or music stimuli). Post hoc analysis used one-way ANOVAs to examine the source of significant differences between interference types on the musical stimuli for MUS and NONMUS individually. All analyses were performed using MINITAB 16.

For the language stimuli, there was no significant difference between MUS and NONMUS on accuracy [$F(1, 20) = 1.00$, $p = 0.32$]. Also, there was no significant difference across the type of interference for accuracy, which is atypical of interference experiments with language.

For the music stimuli, there was a significant difference between MUS and NONMUS on accuracy [F(1, 20) = 10.42, p = 0.004, η_p^2 = 0.07] with MUS being more accurate than NONMUS, as well as a significant difference between types of interference [F(2, 20) = 4.64, p = 0.01, η_p^2 = 0.03]. The one-way ANOVA for MUS indicated a significant difference between static interference and music interference using the Tukey method and Fisher method, where static interference had higher accuracy than music interference. Language interference was not significantly different from either static interference or music interference. The one-way ANOVA for NONMUS did not indicate any significant difference between interference type. One NONMUS trial contained random missing data.

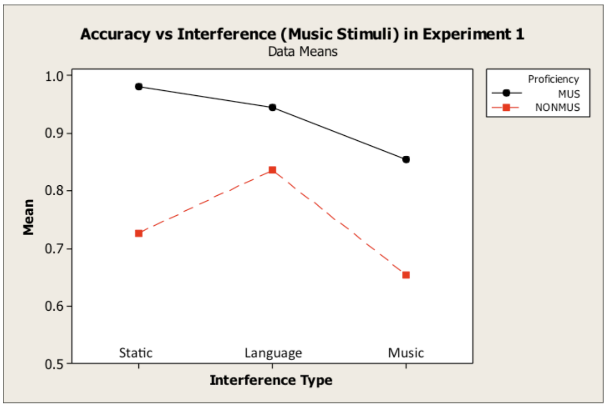

Figure 3: Interaction plot for accuracy vs. interference type on music stimuli for Experiment 1. The solid line and dots represent the average for MUS; the dotted line and squares represent the average for NONMUS.

F. Discussion

As expected from the first hypothesis, there were no significant differences between MUS and NONMUS on accuracy for language stimuli. MUS performed better than NONMUS on trials with musical stimuli, in accordance with the second hypothesis. This is to be expected because of MUS previous experience with music and musical memory tasks. However, there was no difference between interference type, which is unexpected. This is probably due to the ceiling effect of high accuracy on all language stimuli trials.

For MUS, type of interference affected accuracy; music interference resulted in lower accuracy for musical material, while other types of interference (static and language) affect accuracy less. This supports part of the third hypothesis. As for the fourth hypothesis, this experiment contained no significant differences between interference types for NONMUS.

III. EXPERIMENT 2

For this experiment, instead of complete sentences, language interference consisted of lists of five three-syllable words. Instead of complete musical phrases, music interference utilized lists of five tonal patterns from Gordon (1976). Both were spoken or played to fill 5s without extreme distortion of normal prosody or tempo. The change was due to a desire to raise ecological validity using two different means of interfering and examining if both produced similar results.

A. Procedure

Participant requirements were the same for Experiment 2 as Experiment 1. There were a total of 20 MUS (12 men, 8 women), ages 18-22, (M=20.8 years, SD=1.15) and 21 NONMUS (7 men, 14 women), ages 19 to 27, (M=20.95 years, SD=1.96) which completed the study.

B. Design

The design for Experiment 2 was the same as for Experiment 1.

C. Materials

All stimuli for Experiment 2 were the same as for Experiment 1. The words used in the language interference were randomly selected from a list generated by MRC Psycholinguistic Database (Coltheart, 1981). Parameters were set to only include three-syllable words with an imagery rating of 100-400 and concreteness rating of 100 – 400. None of the interference words were used as stimuli. The patterns in the music interference were three-pitch patterns randomly selected from the "difficult" sections of dominant, major subdominant, and minor subdominant pattern types (Gordon, 1976).

D. Procedure

Participants used only the MacBook running Leopard and Shure SRH440 headphones; each session had only one participant at a time, and took an average of 25 minutes. All other procedures were kept constant between Experiment 1 and Experiment 2.

E. Results

One NONMUS was removed from the study due to random missing data, as well as evidence of distraction and noncompliance during testing. Two trials from two other separate participants contained random missing data.

For the language stimuli, there was no significant difference in accuracy between MUS and NONMUS [F(1, 38) = 2.11, p = 0.15] or between interference type [F(2, 38) = 2.01, p = 0.13].

For the music stimuli, there were significant differences in accuracy between MUS and NONMUS [F(1, 38) = 10.25, p = 0.003, η_p^2 = 0.03] and between interference type [F(2, 38) = 13.42, p < 0.001, η_p^2 = 0.05]. The one-way ANOVA for MUS indicated a significant difference between static interference and music interference using the Tukey method and Fisher method, with static interference having higher accuracy than music interference. Language interference was not significantly different from static interference, but was significantly higher from music interference. The one-way ANOVA for NONMUS indicated a significant difference between language interference and music interference using the Tukey method and Fisher method, with language interference having higher accuracy than music interference. Static interference was not significantly different from either language interference or music interference.

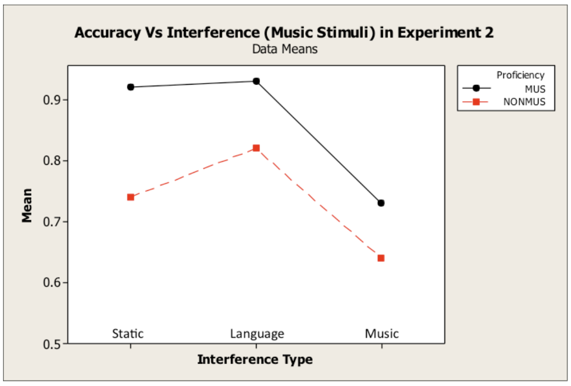

Figure 4: Interaction plot for accuracy vs. interference type on music stimuli for Experiment 2. The solid line and dots represent the average for MUS; the dotted line and squares represent the average for NONMUS.

F. Discussion

As expected from the first hypothesis, there were no significant differences between MUS and NONMUS on accuracy, though a difference in accuracy should have occurred between interference types. This is probably due to the ceiling effect of high accuracy on language stimuli trials.

Again, MUS performed better than NONMUS on trials with musical stimuli, in accordance with the second hypothesis. For MUS, type of interference affected accuracy; music interference resulted in lower accuracy for musical material, while other types of interference (static and language) affect accuracy less. This supports part of the third hypothesis. As for the fourth hypothesis, unlike in Experiment 1, the one-way ANOVA revealed a significant difference between interference type for NONMUS in terms of accuracy, but the results revealed a trend opposite to what was expected. When considering accuracy, language interference was significantly different from music interference, but not from static interference, for accuracy; instead of language interference causing lower accuracy than static interference and similar accuracy to music interference, language interference resulted in higher accuracy than both other types.

IV. GENERAL DISCUSSION

Recall that the four hypotheses were as follows:

1) That musically proficient participants (MUS) would not differ from musically non-proficient participants (NONMUS) on the language stimuli.

2) That MUS would perform more accurately than NONMUS on the musical stimuli.

3) That MUS on music stimuli would perform more accurately with static interference and language interference than with music interference.

4) That NONMUS on music stimuli would perform more accurately with static interference than with language interference or music interference.

Almost all results from Experiment 1 and Experiment 2 agreed, supporting the idea that both interference designs are equally valid. The only differences between the two came from trends that were approaching significance in Experiment 1 that became significant in Experiment 2.

Overall, the language stimuli supported the first hypothesis, that MUS and NONMUS were not significantly different at performance on language-based working memory tasks. However, in previous research with language stimuli and different types of interference, language interference decreases accuracy. This effect is not present prominently in these experiments. When asked about the experiment informally, participants indicated that the words were easy to remember regardless of interference type. This imbalance between remembering numbers of words and numbers of musical notes is also noted in Williamson, Mitchell, Hitch, and Baddeley (2010). Pilot work revealed that performance on comparing four-note sequences approximated performance on comparing seven-letter sequences. Increasing the difficulty of the language task by increasing the number of words or syllables to retain might result in participant performance similar to previous research. This first hypothesis is admittedly weak, as it is predicting the null hypothesis (no difference).

MUS performed better, as expected, than NONMUS on music stimuli, supporting the second hypothesis and the knowledge that experience and expertise improve performance on musical tasks. And the third hypothesis was supported by both experiments, with MUS performing less accurately when retaining music through music interference. The performance trend matched previous research for language stimuli and same-as-stimulus interference (Salame & Baddeley, 1989), which indicated that MUS process music similarly to language—storing sequences and phrases within a subcomponent—but not utilizing the same storage subcomponent as language. Both auditory stimuli did not seem to compete for the same phonological resources, including that they may have used different storage subcomponent spaces. And since they both behaved similarly in terms of interference and recall, they probably used the same component—the phonological loop.

The most interesting finding involved the fourth hypothesis and the difference between interference types on NONMUS performance with music stimuli. Previous research using music stimuli with language interference (as well as language stimuli with music interference) would predict that accuracy should decrease more than static interference but less than with same-as-stimuli interference (Salame & Baddeley, 1989; Deutsch, 1970); however, results of both experiments revealed a spike in accuracy with language interference (Experiment 1 lacked significance but showed the same spike). While this spike is initially unexpected, it may not completely contradict the revised phonological loop model.

For NONMUS, if music is not a meaningful auditory collection, then music would be processed, rehearsed, encoded, and recalled using the same means as other non-language sounds, the articulatory loop. Because language has a storage subcomponent, when language serves as the interference, it can be filed away in its subcomponent and not interrupt music rehearsal as severely as another non-language sound would. So while language enters its storage subcomponent, static and music must compete for the articulatory loop. Described in this matter, the revised phonological loop model would lead researchers to expect language to interfere less than non-language sounds. What remains to be seen is why previous research with tonal stimuli and language interference did not result in the same spike.

Another possibility for the spike in accuracy is that, once again, the word choice affected interference ability. Since the language stimuli were too easy, perhaps the word selection for interference made those trials easier; however, if word choice were the only cause, then there should have been a similar spike for MUS. Future research could test this finding using the same design with a wider population and longer or more complex words, both for stimuli and for interference, or even a different experimental design used to examine working memory, such as articulatory suppression or operation span comparison between language target stimuli and music target stimuli.

In conclusion, musical experience alters perception and processing of auditory stimuli (specifically language and music), and comparing musically-proficient individuals with musically-non-proficient individuals reveals evidence for another component of working memory, specifically the remodeling of the phonological loop to include a temporary storage subcomponent for music. Further research on other meaningful auditory sounds (such as bird calls or engine sounds to people with extensive experience in those areas) could confirm such a redesign, and perhaps expand the design to include a storage subcomponent for each collection of sounds which convey meaning to the listener.

ACKNOWLEDGMENT

This research was supported by Belmont University's Honors Program. The researchers would also like to thank Dr. Lonnie Yandell and Dr. Mark Volker of Belmont University for assistance throughout the experiments. Finally, we thank the US/UK Fulbright Commission and Belmont University's Honors Program for assistance in attending this conference.

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