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MUSICAL SYNTACTIC PROCESSING IN BROCAS APHASIA: A PRELIMINARY STUDY

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ABSTRACT

Broca's aphasics have syntactic comprehension problems in language. Do they also have syntactic comprehension problems in music? This question was motivated by a recent hypothesis regarding the neural relationship of linguistic and musical syntactic processing [1]. We addressed this question using a well-studied paradigm in music cognition known as harmonic priming [2]. Seven Broca's aphasics and ten age-matched controls completed a priming experiment which examined how the processing of a musical chord was influenced by its structural relationship to a preceding harmonic context. While the controls showed normal harmonic priming, the aphasics did not. This argues for overlap in the syntactic processing of language and music. Although the number of aphasics tested in this study was small, the data indicate that this line of research is worth pursuing on a larger scale. Several methodological issues relevant to future research are discussed.

1. INTRODUCTION

Music perception in aphasia has been little studied, despite suggestive older research [3]. Recently, Patel [1] proposed a framework motivating research on this topic. He proposed that linguistic and musical syntax share neural processes (instantiated in overlapping frontal brain areas) which serve to activate domain-specific syntactic representations in posterior brain regions as part of the process of structural integration. This was termed the Shared Syntactic Integration Resource Hypothesis (SSIRH). One prediction resulting from the SSIRH is that individuals who suffer syntactic comprehension problems in language due to frontal brain damage (Broca's aphasics) will also show a disruption of musical syntactic processing.

To test this prediction, Patel suggested testing Broca's aphasics' perception of harmonic relations in music. The motivation for studying harmony perception comes from research showing that listeners enculturated in Western tonal music have rich implicit knowledge of musical harmonic relations, including combinatorial principles for chords which form part of the syntax of tonal music [4,5,6]. Based on the idea that Broca's aphasics have difficulty in activating and integrating syntactic representations in language [7], SSIRH predicts that these individuals will also show impaired activation of harmonic representations, which should disrupt harmonic processing.

To test musical syntactic processing, we chose a harmonic priming task. Harmonic priming refers to the influence of a harmonic context on the processing of a target chord. Numerous studies have shown that a target chord is processed more rapidly and accurately if it is harmonically close to its context (e.g. [8]), and that this is not simply due to the psychoacoustic similarity of the chords but to their distance in a structured cognitive space (e.g. [9]).

At a more detailed level, we sought to examine if the degree of an individual's linguistic syntactic comprehension deficit was related to their performance on harmonic priming tasks. That is, we sought to classify individual Broca's aphasics with regard to the severity of their syntactic deficit in language, in order to relate their syntactic abilities in language and music.

While we were able to sort our aphasics into two groups based on their degree of linguistic syntactic difficulty, we were not able to test a large number of individuals in each group. This influenced the aims of ours study. Specifically, our aims for this preliminary study were: 1) to determine if there is any evidence of abnormal musical processing in Broca's aphasics which would justify further research, and 2) to identify methodological issues which could help guide future studies.

2. METHODS

Stimuli: The musical stimuli consisted of pairs of chords (a prime chord and a target chord), as in the original harmonic priming study of Bharucha and Stoeckig [2]. All chords were major triads built from Shepard tones [10], i.e. each of the three pitch classes in the chord was represented by numerous pure tone components in octave relations. These components spanned a frequency range from 78 to 2350 Hz, with amplitude tapering off at the low and high end. The chords thus had an organ-like timbre and were ambiguous in pitch height. Each chord was 1 second in duration, and the members of each chord pair were separated by 50 ms of silence.

Prime chords were the tonic chords from all 12 keys around the circle of fifths for musical keys. The harmonic relationship between the prime and target chords was either close or distant. When close, the target chord was the tonic chord of the key two counterclockwise steps away on the circle of fifths (e.g. B-flat major target for a C-major prime), and when distant, four counterclockwise steps away (e.g. A-flat major target for a C-major prime). This was modeled on the study of Tekman and Bharucha [9] (experiment 1), who chose these distances because they directly pit cognitive distance against psychoacoustic similarity. For example, a C major chord (C-E-G) shares a common tone with an A-flat Major chord (Ab-C-Eb) but not with a B-flat major chord (Bb-D-F), although the latter is closer in terms of abstract cognitive distance.

Target chords were either tuned or mistuned. Mistuned chords had all frequency components corresponding to the fifth degree of the chord lowered by 35 cents (i.e. all components corresponding to G in the chord C-E-G). This yielded 48 possible pairs of chords (12 primes x 2 target distances x 2 tuning levels), which were presented in a different random order to each participant.

Procedure: All participants first completed a familiarization experiment in which they heard one chord at a time and indicated if it was tuned or mistuned (30 chords were presented, half of which were mistuned). The stimuli were self-paced and feedback was given after each trial. This familiarization experiment was only conducted once, i.e. participants did not repeat the experiment to improve their score, and no participant was excluded on the basis of their performance on this experiment.

Participants next completed a chord priming experiment consisting of 48 trials. The participants were instructed to listen to each pair of chords and judge whether the second chord was well-tuned or mistuned. The experiment was self-paced and feedback was given after each trial.

Stimulus presentation was controlled by Presentation software running on a PC. Sounds were delivered over headphones in a quiet room, and visual feedback was provided via the computer monitor. A research assistant helped to explain the test to participants and answer any questions.

Participants: The participants in the study were 9 Dutch-speaking Broca's aphasics (mean age 60.1 years, range 47 - 72 years, at least 9 months post-stroke) and 12 age-matched controls. The classification of Broca's aphasia was based on scores on the Aachen Aphasia Test (AAT, Dutch version) and an evaluation of spontaneous speech in a standardized interview by three specialists in aphasia. Participants were tested in Nijmegen, The Netherlands at the Max Planck Institute for Psycholinguistics. All aphasics completed an offline syntactic comprehension test for language involving matching spoken sentences to pictures based on syntactically increasingly complex structures (cf. [11]). On the basis of this test they were classified as having either a mild or severe syntactic comprehension deficit. Some aphasics and controls had played musical instruments during their lifetime but none was a professional musician.

3. RESULTS

Familiarization experiment: Controls scored 80.8% correct in discriminating tuned from mistuned chords, and all but one participant scored 70% or higher. Aphasics scored 75.2 % correct, and all but two participants scored 70% or higher. Mean performance by controls and aphasics did not differ significantly ($p=.12$, Mann-Whitney U-test). Thus the two groups were equally able to discriminate tuned from mistuned chords.

Priming experiment: We used a cutoff of 70% correct (out of 48) for a participant's data to be included in the analysis. Data from 2 controls and 2 aphasics were excluded as a result. Thus the resulting number of participants was 10 controls and 7 aphasics.

This report focuses on reaction times (RT) for correct responses to tuned targets which were harmonically close vs. distant from the prime chord. Due to the small number of participants and the individual variability of the responses, control and aphasic data are analyzed separately and statistics are computed using nonparametric methods. Mean control data are shown in Figure 1.

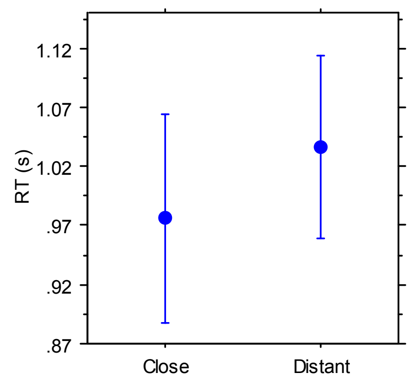

Figure 1: Control group data (mean and s.e.) for correct responses to harmonically close vs. distant target chords.

Figure 1 reveals that controls showed an effect of harmonic distance on their responses: harmonically close targets were responded to faster than distant ones, i.e. a standard harmonic priming effect was observed. (NB: Mean percentages of errors in the two conditions were 6.7% for close targets and 7.5% for distant targets.) The difference between the reaction times in the two conditions was significant ($p < 0.05$, Wilcoxon Signed Rank test). The large error bars reflect a wide range of RTs in both conditions, which can be seen when individual data are plotted, as in figure 2.

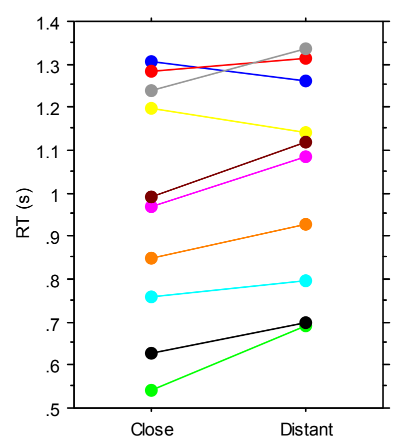

Figure 2: Control data for individual participants.

Figure 2 reveals that the 10 controls varied a good deal in terms of how fast they responded to the stimuli. Nevertheless, 8 out of 10 controls showed priming (RT to close < RT to distant).

Mean aphasic data are shown in Figure 3.

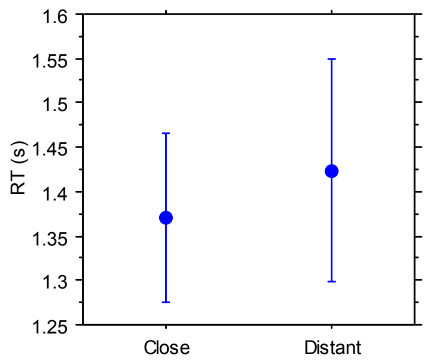

Figure 3: Aphasic group data (mean and s.e.) for correct responses to harmonically close vs. distant target chords.

Figure 3 suggests that aphasics do not show an effect of harmonic distance on their responses, and a statistical test reveals no significant difference between the two conditions ($p = .74$, Wilcoxon Signed Rank test). (NB: Mean percentages of errors in the two conditions were 11.9% for close targets and 8.3% for distant targets.) However, these average results conceal a more interesting picture which emerges when aphasic reaction time data are split into two categories based on the severity of the syntactic comprehension deficit. Data for aphasics with a mild syntactic comprehension deficit are shown in Figure 4, and for aphasics with a severe syntactic comprehension deficit are shown in Figure 5. Because of the small number of individuals in each group, individual data are shown rather than group means.

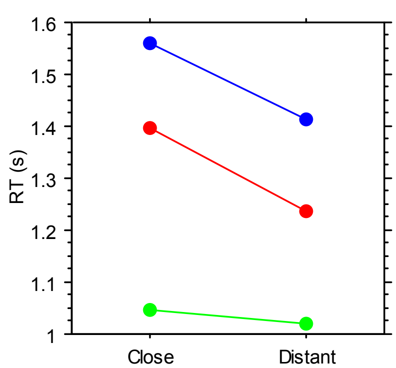

Figure 4: Chord priming data for 3 aphasics with a mild syntactic comprehension deficit in language.

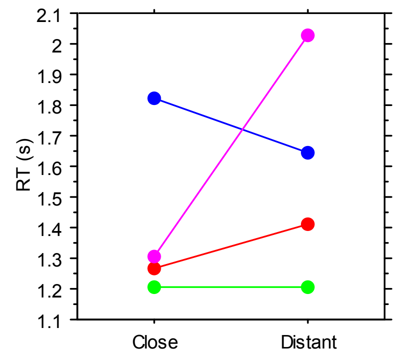

Figure 5: Chord priming data for 4 aphasics with a severe syntactic comprehension deficit in language.

Due to the small amount of data, meaningful statistical analysis is not possible within each group. Nevertheless, two interesting things are apparent. First, across the two aphasic groups only two out of seven individuals showed priming, while four showed reverse priming and one showed no priming. Second, there is a suggestion of an inverse relationship between the severity of the linguistic and musical syntactic comprehension deficits.

4. DISCUSSION

Do Broca's aphasics have syntactic comprehension problems in music? This question is relevant to the larger issue of the cognitive and neural relationship of language and music [1,12,13,14], and is addressed here by using a well-studied paradigm in music cognition, harmonic priming, to test the harmonic perception of Broca's aphasics.

While the controls in our study showed normal harmonic priming, the aphasics did not. This cannot be attributed to a simple failure of the aphasics to discriminate tuned from mistuned chords, as they were roughly comparable to controls in this ability. This allows a meaningful comparison of control vs. aphasic responses to chords as a function of harmonic context. The results show that most aphasics do not show the normal facilitative effect of a close structural relationship of context and target. This is consistent with the view that syntactic harmonic knowledge is not being activated in a normal way in Broca's aphasics, supporting the predictions of the Shared Syntactic Integration Resource Hypothesis [1]. However, the small number of aphasics tested precludes making firm conclusions. The data do indicate, however, that this line of research is worth pursuing on a larger scale.

When aphasic chord priming data are split by the severity of the aphasics' linguistic syntactic comprehension deficit, there is a suggestion of an inverse relationship between syntactic problems in language and music. However, this must be treated with caution as the number of aphasics in each group was small and this study used an offline test for language syntactic abilities. Blumstein et al. [15] have noted that offline and online performance do not always correlate in linguistic tests of aphasics. Thus it would be preferable to have an online syntactic test for language, perhaps a syntactic priming task which would be methodologically similar to the musical task [7,15].

Future studies should also consider including a semantic priming task for the aphasics, to see if harmonic priming performance correlates better with syntactic or semantic deficits on a case-by-case basis. Blumstein has reported a pattern of "hypopriming" for Broca's aphasics in semantic priming tasks [16, 17], suggesting that both syntactic and semantic priming are impaired in this population.

This study raises another issue relevant to future work on music perception in aphasia: the importance of examining individual data. Most harmonic priming studies simply report mean values for reaction times to different conditions. As seen in figures 3-5 of this study, however, mean values can conceal a good deal of interesting information.

Assuming that future research confirms that Broca's aphasics have syntactic comprehension problems in music, what would be the cognitive significance of this finding? First, it would support a cognitive and neural distinction between processing and representation in the mind's handling of syntactic structure [1]. Second, it would support the view that Broca's aphasia reflects damage to domain-general syntactic processes rather than to language-specific syntactic representations (cf. [7,18,19]). Third, it would suggest that linguistic and musical syntactic deficits can be modeled in a common computational framework (cf. [17,20]).

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