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Out-of-Key Notes and On-Beat Silences as Prosodic Cues in Sung Sentences

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Abstract

Violations of musical syntactic expectancies such as out-of-key notes are known to interact with linguistic processing, due to shared syntactic integration resources, located in Broca's area. As these are syntactic integration resource, researchers have assumed that such events negatively affect the processing of language, and that they do not affect semantics. However, the results of this study challenge both assumptions. An online listen-experiment shows that out-of-key notes sometimes do affect semantics. Thirty participants listened to thirty sung sentences in three conditions and rated the plausibility of literal and colored (emotional, ironic or metaphoric) interpretations . Out-of-key notes significantly affected these ratings. Loud rests (on beat silences) did not yield a similar effect.

Introduction

Language and music share several characteristics. Moreover, recent findings indicate that processing language and processing music even rely on shared neural resources (Sammler et al., 2010; Lidji et al., 2009; LaCroix et al., 2015). For example, in line with Patel's Shared Syntactic Integration Resources Hypothesis (SSIRH, Patel, 2003), evidence is found that the processing of musical and linguistic syntax interact in Broca's area (Kunert, 2017). Presumably as a result of this interaction, both neurophysiological and behavioral studies show that violations of musical-syntactic expectancies (VMSEs), such as out-of-key notes, affect the processing violations of linguistic syntactic expectations (VLSEs) (see Kunert, 2017, 18-21, for a review) and that reading grammatically complex sentences while listening to music negatively affects music processing (Kunert, Willems & Hagoort, 2016). As the interaction in Broca's area is purely syntactic (Kunert, 2017) out-of-key notes and unexpected harmonies are claimed not to affect semantics, although in musical analyses it is quite usual to interpret such musical events as meaningful, for example ironic (Burns, 2000), and several studies show that out-of-key notes can evoke specific qualia (Huron, 2006; Arthur, 2018).

The discussion on the possible interaction between VSMEs and semantics is blurred by three problems which occur in several SSIRH-related studies. Firstly they show a biased focus on negative effects, secondly they do not take into consideration a possible effect of prosody, and thirdly they often base their conclusions on edited data in which the original data are incorporated. Examples will follow.

Please note that there is no question about the evidence for the SSIRH. What is questioned here, is the hypothesized negative effect of VMSEs on language processing as a whole. The competing hypothesis here is, that VMSEs might be difficult to process, and thus might pace the processing of simultaneously presented words (Slevc et al., 2009), but ultimately will support language processing, if the VMSEs can be interpreted as meaningful prosodic accents. This might sound paradoxical, but a comparable paradoxical effect, known as foregrounding, is shown in linguistics, literature and film (Miall & Kuiken, 1994; Hakemulder, 2004; Hakemulder, 2008). According to the Musical Foregrounding Hypothesis (MFH, Schotanus, 2015) such an effect is also present in song. The MFH might shed a new light on the debate about VSMEs and semantics, which might lead to the conclusion that indeed this debate is blurred by the three problems mentioned above.

Both a focus on negative effects and the use of edited data can be found in a study by Poulin Charronat et al. (2005). In this study participants heard sung sentences accompanied with eight chords. The last chord was either an tonic chord or a less expected subdominant chord, ant the last word was either a word or a non-word, and if it was a word it was either semantically related or unrelated to the linguistic context. Afterwards, participants had to decide whether the last word was a non-word or not. The researchers found that tonic chords supported the detection of semantically related words as words. Furthermore, their images indicate that unrelated chords support the detection of semantically unrelated words, but they did not report that. Instead they reported that the difference between semantically related and unrelated conditions was larger for targets sung on tonic chords than those sung on subdominant chords. Reporting a difference is reporting edited data, and in this case it masks the positive effect of semantic unrelated chords on the detection of semantically unrelated words. Such a positive effect of unexpected chords would be in line with the results of a study by Curtis et al. (2003) in which unexpected chords support the recognition of unexpected words (and vice versa). Possibly, participants interpret unexpected chords as prosodic accents signaling wrongness, or peculiarity.

Such a mechanism, might also be the key to a study by Koelsch and Steinbeis (2008). In this study participants listened to five-word sentences, presented along with five-chord sequences. A surprising last chord presented along with a low-probe but correct word (such as 'beer' in 'He saw the cool BEER') elicited a so called N5, a brain potential associated with musical meaning. Three years later Carrus, Koelsch and Bhattacharya (2011) found a similar interaction which was close to significance, but furthermore no one has been able to replicate these results. However, studies that tried but failed to replicate them (Carrus, Pearce and Bhattacharya, 2013, among others) do not use stimuli in which the unexpected chord can be interpreted as a reflection of the meaningful unexpectedness of the word combined with it, only Steinbeis & Koelsch (2008) and Carrus et al. (2011) do. Therefore, it is important that the possibility of a prosodic effect of VMSEs on language processing is taken into account.

The third study reporting an interaction between VSMEs and violations of semantic expectancies is a study by Perruchet and Poulin Charronat (2013) who presented participant-paced combinations of chord-sequences with either garden-path or unambiguous sentences. They found that the difference in reading time between the two types of sentences was significantly lower when the chord sequence

was completely in key, than when the chord sequence contained an out-of-key chord. The suggestion was, that the out-of-key chords interact with the semantic garden path, making them more difficult to process. However, a closer investigation of the data reveals that the out-of-key notes did not cause increased reading times for the garden-path sentences but decreased reading times for their unambiguous equivalents. Apparently, the out-of-key chords have somehow supported the processing of the unambiguous sentence. Possibly because it made sense as a prosodic accent. A detailed investigation of the stimuli has to ensure that such an explanation makes sense or not. However, it is no wonder that other studies, designed to assess the claim that VMSEs interact with semantics (such as Kunert, 2017), have failed to replicate the results of this study. These studies used different kinds of sentences as stimuli and did not reckon with a possible prosodic effect of the VSMEs.

To support the claim that VMSEs indeed can function as prosodic cues, and subsequently that WMSEs are sometimes able to affect semantics, an online listen experiment was conducted. The main aim of this experiment was to test whether VMSEs can change the interpretation of ambiguous sung sentences. Apart from out-of-key notes also loud rests (i.e. on-beat silences, London, 1993) will be used as violations of musical syntactic expectancies. Although Honing (2009, 119) suggests that a loud rest does not accentuate notes preceding or following it, it is likely that it does affect the processing of words preceding and following it, at least if it occurs at positions where in speech a silence would be interpreted as a 'pause for effect'. Loud rests cause substantial brain activity, more specifically, a so-called mismatch negativity (Ladinig et al., 2009), so apart from interrupting the linguistic phrase a loud rest might also distract attention. Furthermore, as the mismatch negativity is a preconscious phenomenon, the listener might even misattribute it to the language. Moreover, rhythmic manipulations are known to affect both musical and linguistic syntax (Gordon et al, 2015), and language comprehension (Quené and Port, 2005; Gordon et al, 2011), and they interact with the effect of simultaneously presented out-of-key notes and linguistic syntactic expectancies (Jung et al, 2013). Finally, in speech pauses can be interpreted as prosodical cues (Tyler, 2013).

Method

Participants and Procedure

31 Participants (30 of which completed the whole survey) were recruited via e-mail, Facebook, one of the websites Neerlandistiek.nl or Proefbunny.nl, or by live recruiting in pop-up laboratories in three book shops in Rheden area, the Netherlands. They were between 19 and 78 of age (M = 41,7; SD = 19,2)) and 74% was female. They completed the survey online, and received 5€ if they left their adress. Musical experience is measured by using a translation in Dutch of the Musical Training scale of the Goldsmith Musical Sophistication Index (Bouwer et al., forthcoming; Müllensiefen et al., 2014). Furthermore five questions were asked concerning literary experience. A Factor analysis on these questions resulted in two Factors, one indicating writing experience, and another one indicating disinterest in wording.

Stimuli

Three sets of stimuli were created, all of them consisting of different versions of the same thirty sung sentences. In each condition ten sentences were presented in their original form, i.e. sung fluently and in-key. In another ten sentences the original recording was edited such that two target words were delayed, creating an on-beat silence. In the remainder ten the same words were edited such that they were on beat but out of key. The pitches were changed by one semitone without harming the melodic contour. All sentences were sung a cappella, but preceded by a short piano-intro establishing a rhythm and a key.

There were sixteen target sentences and fourteen fillers sung to ten different melodies. In the target sentences the musically manipulated words all were thought to be ambiguous to a certain extent. Either because they could be interpreted in an ironic, or in a metaphoric, metonymic or very emotional way (with disgust, for example). The fillers were thought to be unambiguous. Furthermore, some of the fillers did not have the two part structure.

After each sentence the participants read three interpretations of the sentence, one of them literal, two of them more or less 'colored' (i.e. ironic, metaphoric, metonymic or very emotional). For example, the interpretations proposed for the sentence 'The shirt I bought last week is pink, did you happen to was it?' (Mijn nieuwe overhemd is rose; heb jij het soms gewassen?, see Figure 1) are:

A. Did you happen to wash my new shirt? I cannot find it. It is pink.
B. I have bought a pink shirt. Did you happen to wash it?
C. My new shirt is suddenly pink. Did you spoil it by washing it?

For each interpretation the participants were asked to rate on a seven point scale to what extent they thought it was plausible or not.

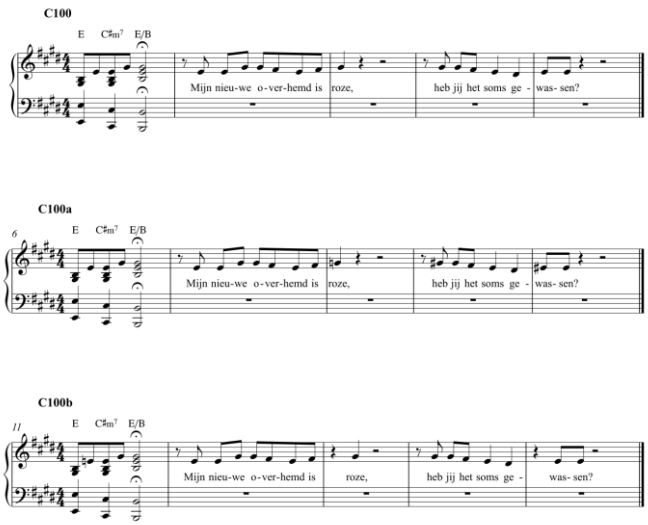

Figure 1. Three versions of one target sentence (The shirt I bought last week is pink; did you happen to wash it) : Fluent in key (top), Out of key (middle) and Loud rest (bottom).

Before recording, all sentences and interpretations were read and rated by an independent colleague unaware of the design of the experiment. When colored interpretations of fillers were rated as somehow reliable, these interpretations were skipped or changed, or the filler was further disambiguated. If neither of the colored interpretations of targets seemed to be somehow plausible, at least one interpretation or the target itself was changed. Furthermore, after recording, the author changed the wording of some interpretations, dependent on his own interpretation of the out-of-key and loud-rest versions.

All sentences were sung by the author (a male baritone), and recorded by Christan Grotenbreg, a professional musician, in his studio. The piano intros were improvised by Christan Grotenbreg on a keyboard connected to ProTools 10 (Desktop recording). The voice was recorded using a Neumann TLM 103 microphone, and an Avalon VT 737 SM amplifier. Digital conversions were conducted using Apogee Rosetta. To avoid confounds concerning purity and timing, voice-treatment software was used: Waves Tune, Renaissance Vox compression, and Oxford Eq.

Analysis

The results were analyzed using both linear and generalized linear Mixed models in SPSS. In line with Quené & Van den Bergh (2004) crossed classified analyses were run with random intercepts for both participant and sentence.

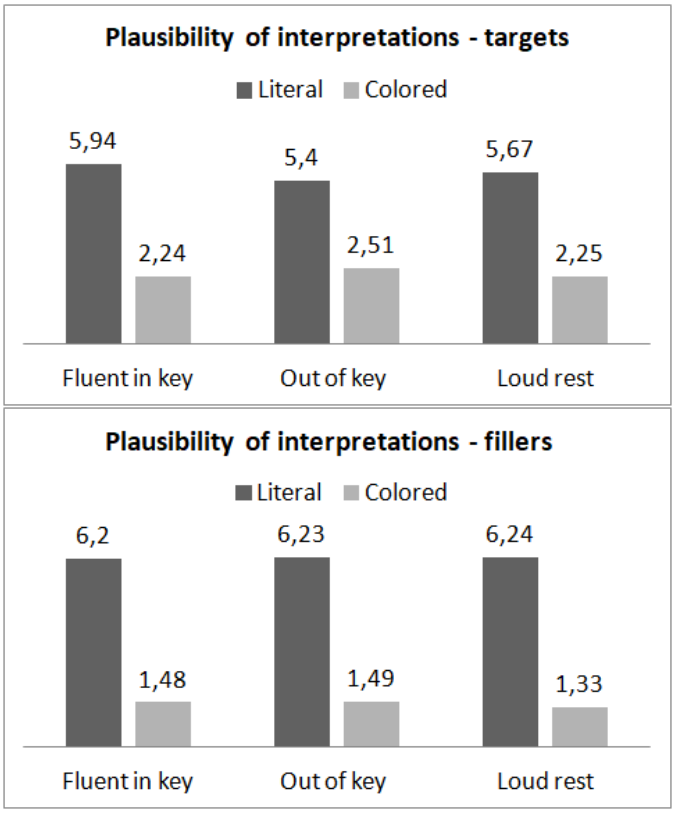

Figure 2. Mean plausibility ratings per condition for literal and colored interpretations of targets (top) and fillers (bottom). SDs fluent-in-key; out of key, and loud rest respectively for targets literal: 1.88; 2.00; 1.79; targets colored: 1,51; 1.92; 1.67; fillers literal: 1.34; 1.29; 1.33; fillers colored: 1.12; 1.08; 0.95.

Results

As Figure 2 shows, literal interpretations have been rated as much more plausible than colored ones in each condition. However, in the conditions out-of-key and loud-rest the difference is smaller. Literal interpretations are rated as slightly less plausible, while colored interpretations are rated as slightly more plausible. Conversely, the plausibility ratings for the fillers are constant across conditions.

In order to investigate whether this effect is significant several Mixed models linear regressions were conducted on the plausibility ratings for interpretations of targets. First, an intercept only model was run with two random intercept factors: participant and sentence. However, as sentence did not show a significant effect and an intercept only model without sentence was slightly more powerful (see Table 1), in the full model just one random effect was defined: participant. Apart from that the main effects of condition (fluent in key, out of key or loud rest), literal or not and condition were tested, plus the interaction between these factors. Musical training, writing experience and disinterest in wording did not show any significant effect and were deleted from the model. As Table 1 shows, there is a main effect for literal or not, but not for condition, although the difference between 'out-of-key' and 'loud rest' is close to significant. However, there is a significant interaction between literal or not and condition, especially for literal*out of key.

Table 1. Mixed models linear regression on Plausibility of interpretation

	df	-2 ll[a]	BIC[b]
Intercept only			
With sentence	4	6684.75	6713.88
Without sentence	3	6684.75	6709.60
Full Model	8	5854.61	5869.16
Type III & Estimates		*beta*	*F / t*
Fixed			
Intercept			1874.50***
Intercept		2.25 (0.13)	17.89***
Condition			0.87
Fluent in key		-0.01 (0.14)	-0.06
Out of key		0.26 (0.14)	1.87[+]
Literal or not			1134.81***
Literal		3.41 (0.17)	19.94***
Cond.*Lit.ornot[c]			5.83**
F.i.k.*literal[c]		0,28 (0.24)	1.19
O.o.k.*literal[c]		-0.53 (0.23)	-2.18*
Random			*Wald Z*
Residual		3.17 (0.12)	26.64***
Subject		0.19 (0.07)	2.86**

[a] -2 Restricted log likelihood

[b] Bayesian information criterion

[c] Condition times literal or not; F.i.k. = fluent in key; o.o.k. = out of key; other interactions are redundant

[+] *p = 0.06; * p < 0.05; ** p < 0.01; *** p < 0.001*

Table 2. Glmm binomial regression on Colored > literal

Model	Df	-2 ll[a]	BIC[b]
Intercept only			
With sentence	4	2380.48	2392.85
Without sentence	3	2333.11	2339.29
Full model	5	2351.11	2357.29
Type III, estimates		*b (SD)*	*F / t*
Fixed effect condition			2.81[+]
Intercept		1.81 (0.27)	6.61***
Loud rest		-0.06 (0.32)	-0.06
Out of key		-0.62 (0.30)	-2.09*
Fluent in key		0	
Random			*Z*
Participant		0.70 (0.29)	2.44*

[a] -2 log pseudo likelihood

[b] Bayesian information criterion

[+] *p* = .061; * *p* < *0.05; ** p < 0.01; *** p < 0.001*

An investigation of the occasions in which one of the colored interpretations was rated more plausible than the literal one revealed that this was more often the case in the out-of-key condition than in one of the other conditions (see Figure 3). However, a binomial regression on colored > literal revealed that the effect of condition is just close to significant, although the parameter estimate for out of key is significant compared to the one for fluent in key (see Table 2).

Because the predicted effect on 'at least one' colored interpretation might be attenuated by including all colored interpretations in the first regression, and because all ratings are the result of weighing up colored and literal interpretations, a third regression was run on a variable 'colored minus literal' representing the difference between ratings for the most plausible colored interpretation and the ratings for the literal interpretation. This regression showed a significant main effect of condition, indicating that the selective use of out-of-key notes significantly decreases the difference between the plausibility of literal and of colored interpretations.

Table 3. Mixed models regression on 'colored minus literal'.

Model	df	-2 l.l.[b]	BIC[c]
Intercept only	4	2496.49	2451.25
Full model	6	2418.13	2436.68
Type III, Estimates		***Estimate (SE)***	***F / Z / t***
Intercept			32.49***
Residual		6.95 (0.49)	14.81***
Participant		2.61 (0.79)	3.31**
Sentence		1.85 (0.76)	2.43*
Fixed effect condition			4.83**
Intercept		-3.01 (0.49)	-6.14***
Loud rest		0.26 (0.29)	0.87
Out of key		0.89 (0.29)	3.02**
Fluent in key			

[a] Levels/Parameters

[b] -2 Restricted log likelihood

[c] Bayesian information criterion

** p < 0.05; ** p < 0.01; *** p < 0.001*

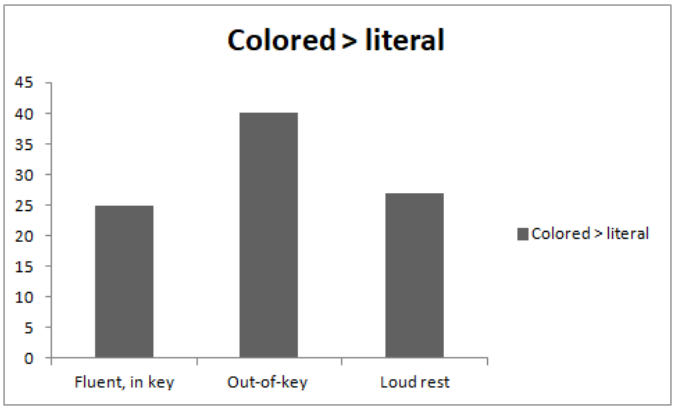

Figure 3. Occasions per condition in which a colored interpretation was rated more plausible than the literal one.

Discussion

The results of this Experiment show that out-of-key notes which are well aligned with ambiguous words can affect the interpretation of a sung sentence, concerning the effect of loud-rest the results are inconclusive. As the manipulation of the target notes was executed digitally in order to be sure that the singer's tone of voice was the same in all conditions, especially the differences between the out-of-key condition and the condition fluent-in-key were quite small. Nevertheless, the results show that out-of-key notes make literal interpretations less plausible, while supporting colored interpretations.

A regression analysis on the plausibility ratings only showed an interaction effect for out of key*literal which indicates that literal interpretations are less plausible in out the out-of-key condition, although the results seem to show an increase of the plausibility of colored interpretations. However, in this analysis all colored interpretations were included, although the hypothesis is that at least one of them would be more plausible in a manipulated version. Furthermore, in at least 15 cases the out-of-key condition has caused a complete shift in interpretation. An additional regression on colored > literal showed that this effect was close to significance. Finally, a regression on the difference between the plausibility of the most plausible colored interpretation and the literal one showed a significant main effect of condition, which was larger than the interaction-effect of out-of-key*condition in the first regression, indicating that the increased plausibility of colored interpretations plays a substantial part.

Furthermore, a comparison with the plausibility ratings for the fillers, which are practically equal in all conditions, with standard deviations half as high as those for the plausibility ratings for targets, shows that the deviant plausibility ratings for literal interpretations in out-of-key versions are not due to an effect of mere difficulty of processing the out-of-key notes but must be related to the ambiguity of the manipulated words and the plausibility of the alternative interpretations.

Unexpectedly, loud rests did not affect the interpretation of target sentences significantly, although the plausibility-ratings for literal interpretations of these target sentences do show a decrease in the loud-rest condition which is not visible in the ratings for fillers. Probably, the lack of significance is due to stimulus creation. Because of unnatural divisions between phonemes, and the absence of other prosodic cues,

the breaks between words and word parts caused by the digitally-created loud rests might have sounded too artificial. Subsequently, the obstruction might be attributed to stimulus editing and not to the intention of the singer. Future research should probably make use of sentences sung with naturally performed loud rests, intended as pause for effect.

Given the fact that the results of this experiment show an interaction of musically syntactic surprises and linguistic semantics, it would be interesting to investigate whether this kind of prosodic interaction would elicit deviant brain potentials. Possibly, the N400 or the N5 will be affected. Concerning loud rests the form of the sentences used here would allow for an investigation of the difference between a within-phrasal loud rest (such as the last one in each sentence) and a between-phrasal loud rest (such as the first one). Possibly, a larger mismatch negativity would be found in the former, which would indicate that indeed there was a language affect, although in this case it did not affect meaning.

Concerning the out-of-key note further research is required as to whether its effect is just a matter of accentuation, or whether there is an intrinsic meaning to it, either related to specific pitch-related qualia (Arthur, 2018), or to the 'wrongness' or peculiarity of the note. Please note that a melodic accent through 'highest pitch' is a result of backward priming, while the out-of-keyness of a note is immediately perceivable.

Finally, as the MFH explains the effect of out-of-key notes in this experiment as a result of accentuation by obstruction, it would be very interesting to test whether simultaneously presented violations of both musical syntactical and linguistic syntactical expectancies are also able to affect language processing in a positive way, or whether in these cases the obstruction is too large to overcome and to make sense of it.

Conclusion

The results of this experiment show that out-of-key notes well-aligned with ambiguous words enhance the plausibility of colored interpretations of sung sentences containing such ambiguous words. Hence, these results support the hypotheses that VMSEs can work as prosodic accents, and that VMSEs working as prosodic accents can interact with semantics. Possible prosodic effects should therefore always be taken into account in research concerning the interaction between VMSEs.and the processing of language. The results of this experiment do not support the hypothesis that loud-rests affect the plausibility of colored interpretations as well. Possibly due to stimulus creation.

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