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Research Report

Noise occlusion in discrete tone sequences as a tool towards auditory predictive processing?

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ABSTRACT

The notion of predictive coding is a common feature of many theories of auditory information processing. Experimental demonstrations of predictive auditory processing often rest on omitting predictable input in order to uncover the prediction made by the brain. Findings show that auditory cortical activity elicited by the omission of a predictable tone resembles the activity elicited by the actual tone. Here we attempted to extend this approach towards using noises instead of omissions in order to capture a more prevalent case of degraded sensory input. By applying a subtraction approach to remove ERP effects of the noise itself, auditory cortical activity elicited "behind" the noise was uncovered. We hypothesized that ERPs elicited behind noise stimuli covering predictable tones should be more similar to ERPs elicited by the actual tones than when the same comparison is made for unpredictable tones. ERP results during passive listening partly confirm this hypothesis, but also point towards some methodological caveats in this particular approach towards studying neural correlates of predictive auditory processing due to contributions from predictability-unrelated factors. A follow-up active listening condition indicated that participants were *not* more likely to perceive the tone sequence as continuous when a predictable tone was covered with noise than when this pertained to an unpredictable tone. Overall, the noise-based paradigm in its present form was not shown to be successful in revealing predictive processing in perceptual judgments or early neural correlates of sound processing. We discuss these findings in the contexts of predictive processing and illusory auditory continuity.

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1. Introduction

The auditory system is challenged with processing incoming information in real time due to the ephemeral nature of its input. Many current theories of brain functioning posit that the real-time processing need is partly alleviated by the exploitation of predictability in the auditory input (Arnal and Giraud, 2012; Baldeweg, 2006; Friston, 2005; Winkler et al., 2009). Predicting forthcoming signals greatly reduces processing load once the signals arrive at the sensors (Sinkkonen, 1999), and it has the additional advantage of compensating for missing sensory information in case of disturbances by extraneous noise (Obleser and Kotz, 2010).

Despite considerable research effort, the precise neural correlates of auditory predictive processes are still under debate (see e.g. Bendixen et al., 2012, for a review). Many studies have used "late" (~150 ms post-stimulus) responses such as the mismatch negativity. It has, however, been regarded as implausible that these would reflect bottom-up prediction error (Yordanova et al., 2012) on the grounds that they appear too late to reflect error signals from lower processing levels, and that they carry contributions from "top-down" processing levels. Other authors have long argued that the mismatch negativity reflects an update of the underlying predictive model rather than the prediction error itself (Winkler et al., 1996; Winkler and Czigler, 1998). Consequently, researchers have been looking for earlier neural correlates of prediction and prediction error in the brain (cf. Grimm and Escera, 2012; Escera et al., 2014).

One approach has been to make the occurrence of a certain stimulus highly predictable, but then to omit this stimulus unexpectedly (Bendixen et al., 2009; Hughes et al., 2001; Raij et al., 1997; SanMiguel et al., 2013a,b; Wacongne et al., 2011). This omission-based approach provides the opportunity to unveil ERP correlates of auditory prediction in the absence of bottom-up sensory input. Specifically, it allows examining whether the auditory system unfolds activity during the omission that is similar to the activity elicited by processing the stimulus if it were present (e.g., Bendixen et al., 2009; Hughes et al., 2001; Raij et al., 1997). Such similarity can be interpreted in terms of the pre-activation of a sensory template of the predictable stimulus (SanMiguel et al., 2013a,b). Neural correlates consistent with the pre-activation account have been observed immediately after sound onset, covering the auditory middle-latency components (Hughes et al., 2001), the latency range of the P50 (Bendixen et al., 2009) as well as a sub-component of the auditory N1 component (SanMiguel et al., 2013b).

Yet as compelling as the omission approach may be in showing the elicitation of auditory sensory activity in the absence of sensory input ("hearing silences", SanMiguel et al.,

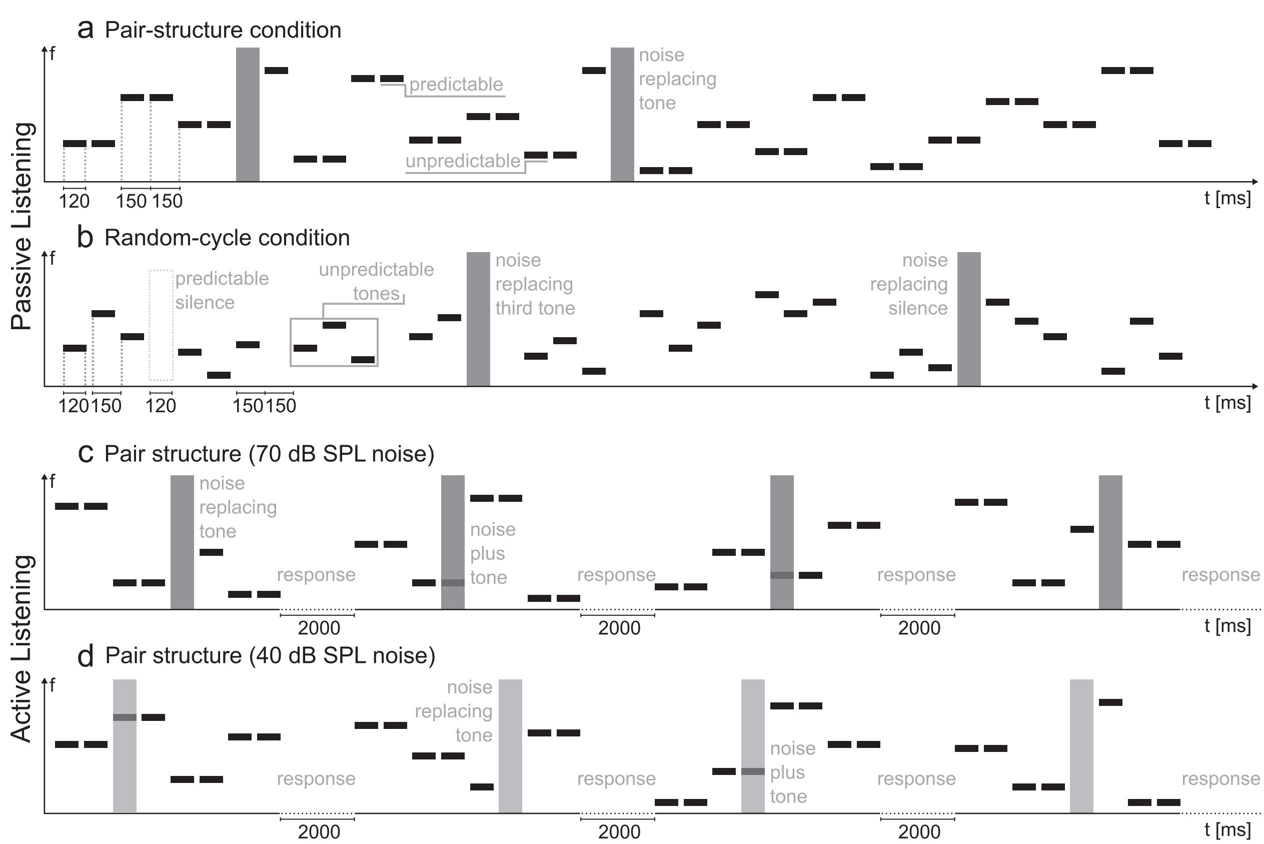

Fig. 1 – *Exemplary stimulus sequences.* a) Pair-structure condition as presented during passive listening. b) Random-cycle condition as presented during passive listening. c) Stimulus sequence during active listening with 70 dB SPL noise (same level as during passive listening). d) Stimulus sequence during active listening with 40 dB SPL noise (control condition). The *x* axis of each panel represents time, the *y* axis represents frequency. Noise stimuli are illustrated by gray rectangles covering the whole frequency spectrum of the tone sequences; shading indicates noise level. For illustration purposes, the actual number of tones preceding and following the noises (6–11 each) in panels c) and d) was considerably reduced.