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Brief article

Got rhythm... for better and for worse. Cross-modal effects of auditory rhythm on visual word recognition

Renaud Brochard [a,b,*], Maxime Tassin [b], Daniel Zagar [c]

[a] Institut Universitaire de France, France
[b] Université de Bourgogne, Pôle AAFE, Esplanade Erasme, 21000 Dijon, France
[c] Université de Lorraine, Campus Lettres et Sciences Humaines, Bd Albert 1er, BP 13397, 54015 Nancy, France

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ABSTRACT

The present research aimed to investigate whether, as previously observed with pictures, background auditory rhythm would also influence visual word recognition. In a lexical decision task, participants were presented with bisyllabic visual words, segmented into two successive groups of letters, while an irrelevant strongly metric auditory sequence was played in a loop. The first group of letters could either be congruent with the syllabic division of the word (e.g. val in val/se) or not (e.g. va in va/lse). In agreement with the Dynamic Attending Theory (DAT), our results confirmed that the presentation of the correct first syllable *on-beat* (i.e. in synchrony with a peak of covert attention) facilitated visual word recognition compared to when it was presented *off-beat*. However, when an incongruent first syllable was displayed *on-beat*, this led to an aggravation of impaired recognition. Thus, our results suggest that oscillatory attention tapped into cognitive processes rather than perceptual or decisional and motor stages. We like to think of our paradigm, which combines background auditory rhythm with segmented visual stimuli, as a sort of temporal magnifying glass which allows for the enlargement of the reaction time differences between beneficial and detrimental processing conditions in human cognition.

1. Introduction

One of the most remarkable properties of the human brain is that its activity can be entrained by external temporal regularities (Grahn & Rowe, in press; Nozaradan, Peretz, Missal, & Mouraux, 2011). Consequences are ubiquitous in human behavior but the most obvious outcome of this universal cognitive ability is reflected in people's spontaneous periodic tapping of foot or hand along with the beat, i.e. the underlying pulse, of musical rhythms (Large, 2008; Large & Kolen, 1994; Repp, 2005; Van Noorden & Moelants, 1999). The induction of meter, as reflected by the perception of some regularly-spaced time positions as being more salient (strong beats) than others (weak beats), conveys to people information on when to listen to and/or when to move their body along with the beat (Drake, Jones, & Baruch, 2000). Even 3-day-old newborns' brain activity has been shown to reflect an early sensitivity to violations of the regular beat conveyed by background music (Winkler, Haden, Ladinig, Sziller, & Honing, 2009). In the present research, our general objective was to investigate the effects of entrainment with an irrelevant auditory rhythm on performance in a visual task.

Musical meter has been shown to very efficiently drive listeners' attention across time (Large, 2008). Auditory sequences with a strongly metric structure are more efficiently perceived, reproduced and/or memorized (e.g. Essens & Povel, 1985; Jones, 2010; Jones, Kidd, & Wetzel, 1981; Patel, Iversen, Chen, & Repp, 2005). Although metric

* Corresponding author. Address: Université de Bourgogne, Pole AAFE, Esplanade Erasme, Dijon 21000, France. Tel.: +33 380 39 55 18; fax: +33 380 39 39 90.
E-mail address: renaud.brochard@u-bourgogne.fr (R. Brochard).

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processes have long been thought to be restricted to the auditory domain, they have recently been described in other sensory modalities (see for example Brochard, Touzalin, Després, and Dufour (2008), Grahn (2012), Trainor, Gao, Lei, Lehtovaara, and Harris (2009), for demonstrations in the tactile, visual and vestibular domains respectively). Moreover, cross-modal benefits of auditory meter have recently been described in vision. Escoffier, Sheng, and Schirmer (2010) recently reported that observers were faster at discriminating between upright and upside-down pictures (faces or buildings) when the visual stimulus occurred on-beat, i.e. in synchrony with a strong metric position of a background auditory rhythm, as compared to when it was displayed off-beat, i.e. out of synchrony with the implied musical pulse.

These results have been interpreted in light of Jones' Dynamic Attending Theory – DAT (Jones & Boltz, 1989; Large & Jones, 1999) – which assumes that strong beat positions correspond to peaks of oscillatory attention. Thus, any perceptual event in phase with a peak of attention is more expected (Ellis & Jones, 2010; Jones & Boltz, 1989), is allocated more resources (Abecasis, Brochard, Granot, & Drake, 2005; Brochard, Abecasis, Potter, Ragot, & Drake, 2003) and is thus better processed. Many studies have confirmed the validity of the DAT (e.g. Ellis & Jones, 2010; Jones, Moynihan, Mackenzie, & Puente, 2002, see Large, 2008) since its initial formulation in 1976 by Jones.

So far, the DAT has typically been assessed by presenting information which was always useful to efficiently perform the prescribed task. What would happen if a misleading piece of information were presented on-beat, i.e. on a peak of covert auditory attention? According to the DAT, emphasizing misleading information should lead to an aggravation of the negative consequences on stimulus processing. This question could not be tested with the stimuli that have been used until now because they were either single tones or pictures presented in full and at once. Indeed, such stimuli, presented in their entirety, could never be misleading since they always corresponded to a response to be given. One way to test synchrony effects on misleading information would be to present a stimulus broken down into subparts. In the present research, we decided to adapt Escoffier et al. (2010) paradigm by asking participants to perform a lexical decision task (LDT) on bisyllabic visual words.

One advantage of using words is that they can be presented into two consecutive parts. Moreover, this temporal segmentation can be manipulated in order to either facilitate or impair stimulus processing depending on whether the stimulus division corresponds to their syllabic boundary (e.g. mo/ral) or not (e.g. mor/al). Indeed, using parsed presentation, Mewhort and Beal (1977) showed that visual word recognition was drastically impaired when groups of letters serially presented on screen were incongruent with the syllable boundaries (e.g. ind/ust/ry) than when they were congruent (e.g. in/dus/try).

Using segmented word presentation enables us to test the synchrony effects of the background rhythm in relation to the timing of the first syllable. Actually, the processing of the first syllable has been reported to be an important step in visual word recognition (Mathey & Zagar, 2002; Mathey, Zagar, Doignon, & Seigneuric, 2006; Perea & Carreiras, 1998). Thus, comparing on and off-beat presentation of the first syllable may allow us to dissociate potential specific effects of oscillatory covert attention on advanced cognitive processes (such as linguistic mechanisms) from its impact on later (decisional and motor) stages.

Based on Escoffier et al.'s (2010) results on pictures, a global effect of synchrony on visual word recognition should be expected. According to DAT, subjects should be faster and more accurate in processing words whose first syllable occurs in synchrony (compared to out of synchrony) with a strong beat, i.e. on a peak of covert attention driven by the metric structure of the auditory sequence. Based on Mewhort and Beal's (1977) study, our participants were expected to be faster and more accurate when the first letters of a word corresponded to its correct first syllable (with either a CV or CVC structure: e.g. mo/ral vs. mor/al or mor/se vs. mo/rse).

However, and more interestingly, we hypothesized that these two factors (synchrony and syllabic congruency) could interact, which might lead to the cancellation of the simple effects of each factor. In fact, if the first syllable of the word is presented on-beat, it should be allocated more attention which would then lead to an enhancement of the benefits of the correct syllabic parsing on word recognition. Conversely, if a series of letters not corresponding to the first syllable of the word is displayed in synchrony with the beat, more attention would be allocated to a misleading piece of information. Therefore, this should lead to the aggravation of the processing costs due to incorrect syllable parsing. Thus, we expected both positive and negative effects of rhythmic auditory attention on visual word recognition depending on the relevance of the first letters displayed on-beat.

2. Method

2.1. Participants

Thirty-two undergraduate students from the University of Dijon participated in the experiment (27 females, 5 males, mean age: 21.5 years, SD = 2.7). They were native French speakers and did not report any impairment in language, visual or auditory perception.

2.2. Auditory sequence

We played a slightly slower version of the rhythmic sound sequence used by Escoffier et al. (2010). This sequence consisted of two bass drum sounds followed by three snare drum sounds (all had a duration of 100 ms). This rhythmic pattern was designed in order to induce a 4-beat metric structure (with 800 ms Inter Onset Interval between two beats, i.e. 75 beats per minute, see Fig. 1). The last two snare drums (10 dB softer) were played 200 ms before and after Beat 3, creating a syncopation and increasing expectancies on Beat 4 (on which no sound was ever played). For details about the experimental validity of this sequence see Escoffier et al. (2010). The se-