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Global precedence effect in audition and vision: Evidence for similar cognitive styles across modalities

Lucie Bouvet [a,b,*], Stéphane Rousset [a,b], Sylviane Valdois [a,b,d], Sophie Donnadieu [a,c]

[a] Laboratoire de Psychologie et Neurocognition (UMR CNRS 5105), France
[b] Université Pierre Mendès France, BP 47, 38040 Grenoble Cedex 9, France
[c] Université de Savoie, BP 1104, 73011 Chambéry cedex, France
[d] Centre National de la Recherche Scientifique, France

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ABSTRACT

This study aimed to provide evidence for a Global Precedence Effect (GPE) in both vision and audition modalities. In order to parallel Navon's paradigm, a novel auditory task was designed in which hierarchical auditory stimuli were used to involve local and global processing. Participants were asked to process auditory and visual hierarchical patterns at the local or global level. In both modalities, a global-over-local advantage and a global interference on local processing were found. The other compelling result is a significant correlation between these effects across modalities. Evidence that the same participants exhibit similar processing style across modalities strongly supports the idea of a cognitive style to process information and common processing principle in perception.

1. Introduction

The comprehension of perceptual relations between the whole and its parts has always been challenging. A striking example of the complexity of the whole-part (or global–local) relations is the painting "Autumn" by Giuseppe Arcimboldo (1573), which represents the portrait of a man composed of vegetables and fruits. As the portrait is recognizable at first sight, it takes longer to become aware that it is not composed of regular face features. A large body of research has been carried out focussing on the relations between global and local features. It has been suggested that this distinction may define a general perceptual function (Ivry & Robertson, 1998) that would account for the global and local processing distinction in all modalities. However, the question of global–local processing has been mainly addressed in the visual modality, and evidence is lacking that this dichotomy further applies to other modalities. This paper directly addresses this issue in investigating whether the global–local distinction applies to both the visual and the auditory modality and if there is a common perceptual mechanism across modalities.

When we perceive natural scenes, global and local information are semantically dependent, perception of the forest can help perceiving the trees and vice versa. To go through this methodological issue, Navon (1977) used hierarchical shapes in the visual modality to independently assess global and local processing and investigate how these two processing levels do interact. The global and local levels of processing were dissociated by arranging local elements to construct a global shape. Local elements and the global shape could be congruent or not (e.g., a big "S" composed of small "Ss" or small "Hs"). Navon reported first, that participants were faster at identifying global shapes than local elements and second, that they were disturbed by the identity of the global shape when asked to identify local elements in the non-congruent condition. These findings illustrate the Global Precedence Effect (GPE). The observation of this effect leads to two conclusions: that global information is available sooner than local information and that global processing is automatic: it cannot be avoided despite explicit instruction to focus attention at the local level. Although it is a robust effect, the GPE can be modulated or reversed by experimental conditions or stimuli's characteristics (for a review, see Kimchi, 1992). For example, many features as visual angle of the global form and local elements, sparsity of elements, duration of exposure, spatial uncertainty (Lamb & Robertson, 1988) and the nature of stimuli (Poirel, Pineau & Mellet, 2006) are known to affect the GPE so

* Corresponding author at: Laboratoire de Psychologie et Neurocognition (UMR CNRS 5105), Université Pierre Mendès France, BP 47, 38040 Grenoble Cedex 9, France. Tel.: +33 47650823564.
E-mail address: lucie.bouvet@upmf-grenoble.fr (L. Bouvet).

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much so that an opposite effect, a local precedence, can be sometimes obtained.

Parallel processing of global/local information –where information is simultaneously processed at the two levels but local processing may begun before local processing is fully completed –has been proposed to explain the GPE (Navon, 1981). This conception of a temporal overlap between the two levels of analysis converges toward a more general model of the visual system, the iteration model, where global information is re-injected in the visual system via a top-down process (Bullier, 2001). The iteration model is supported by neuroimaging and EEG data (Beaucousin et al., 2011; Peyrin et al., 2010). The GPE might then be due to the coarse to fine integration of global and local information, driven by visual spatial frequencies (Hubner, 1997; Hughes, Nozawa & Kitterle, 1996). Low spatial frequencies –providing global information– are processed by the dorsal visual path whereas the ventral visual path processes high spatial frequencies –providing local information– (Badcock, Whitworth, Badcock & Lovegrove, 1990). Because the visual dorsal pathway is faster than the ventral one, "global" information (outcome of low and average spatial frequencies) is available sooner than "local" information (outcome of the spatial high frequencies). This initial low-pass visual analysis can serve to refine subsequent processing of the high spatial frequencies conveyed by the parvocellular visual channel of the ventral visual pathway (Peyrin et al., 2010).

Beyond the GPE explanation, it is noteworthy that there is a hemispheric specialization for global and local processing. Indeed, left brain-damaged patients primarily exhibit a deficit in local elements' identification whereas right brain-damaged patients are disturbed in global forms' identification (Lamb, Robertson & Knight, 1990). Furthermore, neuroimaging studies on healthy participants demonstrated that the right hemisphere was more activated during global processing but the left hemisphere during local processing (Fink et al., 1996). More recently, it has been demonstrated that visual spatial frequencies (Hubner, 1997) are differentially processed by each hemisphere. Low spatial frequencies –providing global information– mainly rely on the right hemisphere whereas high spatial frequencies –providing local information– mainly rely on the left hemisphere (Peyrin, Chauvin, Chokron & Marendaz, 2003). Thus, local and global visual elements seem to be processed by the left and right hemispheres respectively due to hemispheric specialization for spatial frequencies.

The question has been raised whether the same global–local processing differentiation could be found in other modalities (Ivry & Robertson, 1998), with a focus on audition which appears as the direct counterpart to vision (List, Justus, Robertson & Bentin, 2007; Sanders & Poeppel, 2007). The global–local auditory assumption is then assessed asking participants whether two unfamiliar melodies are identical or not. The different pairs are characterized by differences at either the global or local level. The local level is defined by the intervals –the pitch distance– between two notes whereas the global level corresponds to the melodic contour as defined by the pitch direction between notes independently of the pitch value. The reasons why differences in interval changes can be attributed to local processing while contour changes rather rely on global processing are threefold. First, intervals are small units embedded hierarchically in a larger unit, the contour. Second, it has been demonstrated that non-musicians were more prone to use the contour than the interval cue to discriminate melodies, which implies that for non-musicians, melodic contour is a more salient cue to process melody than intervals (Peretz & Morais, 1987). Third, these two musical features involve hemispheric specialization. Studies of brain damaged patients revealed that patients who suffer from a left temporal lesion can perceive the contour but not the interval change whereas right temporal brain-damaged patients are impaired in the processing of both the contour and the interval (Liegeois-Chauvel, Peretz, Babai, Laguitton, & Chauvel, 1998; Peretz, 1990). This observation provides evidence that the contour and the interval features are hierarchically organized: the interval information cannot be processed if the contour information is not processed either. The study of Liegeois-Chauvel et al. (1998) also revealed that the superior temporal gyrus is necessary for melody processing and more particularly its posterior part. Taken together, these findings provide converging evidence that contour change detection involves global processing (right hemisphere) whereas interval change detection further relies on local processing (left hemisphere). Furthermore, the hemispheric specialization in audition seems to be analogous to vision, the global structure being preferentially processed by the right hemisphere, the local elements by the left.

However, the only fMRI study carried out on healthy participants failed to replicate the global and local processing distinction at the hemispheric level (Stewart, Overath, Warren, Foxton, & Griffiths, 2008). Contour processing was found to activate the left posterior superior temporal sulcus selectively while interval processing activated the same region bilaterally. Although activation is enhanced for interval processing –thus supporting the hierarchical view of contour–interval information–, the expected lateralization of processing for these elements is not observed. Furthermore, the global–local processing assumption in audition raises some methodological issues. Indeed, even if intervals and contour form a hierarchical structure, these two features cannot be manipulated independently (Justus & List, 2005). A melodic contour change always involves a modification of the interval; therefore a global modification cannot be done without a concomitant local change. Hence, addressing global–local processing in audition through manipulation of contour–interval features is all the more questionable.

To compensate for these limitations, recent studies developed new sets of hierarchical auditory stimuli to parallel global–local stimuli in vision. For example, based on evidence that the two fundamental features of auditory objects are frequency and time, Justus and List (2005) used high–low and slow–fast stimuli in which the two global–local dimensions can be manipulated independently. Using a divided attention auditory task, they observed facilitation of target perception at one level (global or local) when the same level of processing was required on the previous trial, thus a priming effect very similar to that observed in vision (Robertson, 1996). A late mismatch negativity, which provides evidence for automatic discrimination of the auditory object properties, was also observed for slow (global) stimuli (List et al., 2007). Sanders and Poeppel (2007), using an identification task with slow–fast stimuli –which inspired the auditory task we designed for the current study– reported an auditory GPE. Better and faster responses were observed on global (slow stimuli) than on local (fast stimuli) forms and perception of local elements was disturbed by the global form for incongruent stimuli. Overall, these auditory paradigms have been designed to parallel the original paradigm of Navon (1977) in vision.

However, to our knowledge, no study has ever directly compared global and local processing in vision and in audition within the same participants. To reinforce a unifying perception processing theory, it is crucial to demonstrate that the same mechanisms are involved in global–local processing in both modalities. It is also necessary to demonstrate that the individuals who show a GPE in vision further show a GPE in audition. In the current study, two tasks were designed using the same identification paradigm, which manipulated global and local processing in vision and in audition. The visual task used the classical global and local hierarchical stimuli of Navon (1977). The auditory task used the fast–slow stimuli designed by Justus and List (2005) but within the identification task proposed by Sanders and Poeppel (2007). The choice of these stimuli was motivated by evidence that time is a better counterpart to visual spatial frequency than frequency. If the same mechanisms underlie auditory and visual processing, GPE should be observed both in audition and in vision and a correlation was expected between these two effects.

2. Method

2.1. Participants

Twenty right-handed non-musician young adults (seven males) from the Grenoble urban community participated in this study.