Behavioural Brain Research 271 (2014) 354–364

Contents lists available at ScienceDirect

Behavioural Brain Research

journal homepage: www.elsevier.com/locate/bbr

Research report

The processing of chimeric and dichotic emotional stimuli by connected and disconnected cerebral hemispheres

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HIGHLIGHTS

- Chimeric and dichotic stimuli were presented to two split-brain patients (D.D.V. and A.P.).
- Stimuli conveyed happy/sad expressions and participants judged their emotion content.
- The total split-brain patient D.D.V. neglects visual stimuli in the left hemifield.
- A.P. shows a right-hemispheric dominance in unimodal analysis.
- The valence hypothesis is confirmed in bimodal conditions by A.P. and the control group.

ARTICLE INFO

Article history:
Received 2 June 2014
Received in revised form 16 June 2014
Accepted 18 June 2014
Available online 24 June 2014

Keywords:
Audio-visual integration
Split-brain
Chimeric face
Dichotic stimulation
Hemispheric asymmetry

ABSTRACT

Hemispheric asymmetries have been widely explored in both the visual and the auditory domain, but little is known about hemispheric asymmetries in audio–visual integration. We compared the performance of a partially callosotomized patient, a total split-brain patient and a control group during the evaluation of the emotional valence of chimeric faces and dichotic syllables (an emotional syllable in one ear and white noise in the other ear) presented unimodally (only faces or only syllables) or bimodally (faces and syllables presented simultaneously). Stimuli could convey happy and sad expressions and participants were asked to evaluate the emotional content of each presentation, using a 5-point Likert scale (from very sad to very happy). In unimodal presentations, the partially callosotomized patient's judgments depended on the emotional valence of the stimuli processed by the right hemisphere, whereas those of the total split-brain patient showed the opposite lateralization; in these conditions, the control group did not show asymmetries. Moreover, in bimodal presentations, results provided support for the valence hypothesis (i.e., left asymmetry for positive emotions and vice versa) in both the control group and the partially callosotomized patient, whereas the total split-brain patient showed a tendency to evaluate the emotional content of the right hemiface even when asked to focus on the acoustic modality. We conclude that partial and total hemispheric disconnections reveal opposite patterns of hemispheric asymmetry in auditory, visual and audio–visual emotion processing. These results are discussed in the light of the right-hemisphere hypothesis and the valence hypothesis.

1. Introduction

Studies on the cerebral lateralization of emotional processing have shown variable patterns of results, and the aspect of hemispheric asymmetry in this field still remains controversial [1]. According to the right-hemisphere hypothesis [2–4], a right-hemispheric dominance would underlie all aspects of emotional processing. On the other hand, according to the valence hypothesis [5–7] a right-hemispheric superiority would underlie the processing of negative emotions, whereas a left-hemispheric superiority would underlie the processing of positive emotions.

Hemispheric asymmetries in perception have been explored by means of several paradigms. In the auditory domain, the organization of cerebral auditory pathways makes it possible to evaluate the

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http://dx.doi.org/10.1016/j.bbr.2014.06.034
0166-4328/

contribution of each hemisphere by presenting different stimuli in the two ears (dichotic listening). Exploiting this fact, a number of studies have shown that the presentation of an acoustic stimulus in one ear leads to a higher activation in the contralateral hemisphere (e.g., right ear/left hemisphere) rather than in the ipsilateral hemisphere [8,9]. In particular, the dichotic listening paradigm reveals a right ear advantage (REA), indicating a left-hemispheric superiority in linguistic processing [10,11], which has also been shown in ecological contexts [12]. The REA seems to be attributable to the involvement of the corpus callosum (CC) and the auditory cortex, besides attentional factors (see [13] for a review). Moreover, dichotic listening has been used to investigate the lateralization of emotional processing in the auditory verbal and nonverbal domains [14]. For example, Erhan and colleagues [15] asked participants to categorize emotional prosody of dichotically presented nonsense syllables as having positive or negative intonation, and they found a left ear advantage (LEA), even if they underlined an opposite electrophysiological correlate, namely a higher amplitude of the N100 component in the left rather than in the right hemisphere. These authors proposed that such a pattern of event-related potentials reflects phonetic analysis but that emotional evaluation is processed in the right hemisphere, thus supporting the right-hemisphere hypothesis. Of note, however, Erhan and colleagues pointed out that the LEA was stronger for negative than for positive emotions ([15], see also [72]). On the other hand, Herrero and Hillix [16] found a general lower recognition score for negative than positive emotional intonation sentences, and a significant interaction between the presentation ear and the emotional valence of stimuli, with a specific lowering of scores for the negative emotional sentences presented in the right ear. Schepman et al. [17] have recently confirmed this pattern of results, providing further support for the valence hypothesis.

Other controversial results were also obtained in EEG and neuroimaging studies in which different paradigms than dichotic listening were used. Recording event-related potentials and skin conductance, Meyers and Smith [18] did not find asymmetry in nonverbal affective stimuli processing. Nevertheless, in a functional magnetic resonance imaging study, Wildgruber and colleagues [19] found a stronger activation of the right hemisphere for acoustic stimuli with both positive and negative valence, thus supporting the right-hemisphere hypothesis.

Cerebral lateralization has also been largely studied in the domain of visual perception. Specifically, a paradigm used to investigate cerebral asymmetries in face processing is that of the chimeric faces [2], that are created by juxtaposing the left and right halves of two distinct faces. Studies that made use of chimeric faces showed that the right hemisphere is more specialized for face processing than the left hemisphere [20]. Also in this context, however, contrasting results have been obtained as regards emotion processing. Presenting chimeric emotional faces, Drebing and colleagues [21] provided support for the right-hemisphere hypothesis [21]. Killgore and Yurgelun-Todd [22], on the basis of an fMRI study, concluded that the valence and the right-hemisphere hypothesis are not mutually exclusive, but they should be considered as different possibilities to understand facial emotion processing. A similarly unclear pattern of results has been achieved by exploiting bilateral presentations of two emotional faces or unilateral presentations of one face, providing evidence in support for both the right-hemisphere hypothesis [23,24] and the valence hypothesis [25–27].

With regard to audio–visual integration, an important question is whether the fusion of multisensory inputs leads to a combination of the processing activities involved by each of the two sensory modalities considered in isolation, or whether the information presented in one sensory modality predominates over that presented in the other modality. Of note, a number of studies showed that multisensory integration is automatic and unintentional, although other studies suggested a different point of view (see [28] for a review). Collignon and colleagues [29] asked participants to classify vocal and visual stimuli according to their emotion content, finding that the categorization improved when vocal and visual expressions were congruent and that, in the incongruent conditions, participants based their evaluations mainly on the visual component (visual capture). On the other hand, Petrini et al. [30] found the opposite result, with the acoustic information prevailing during the evaluation of incongruent audio–visual emotional stimuli (auditory capture). Thus, it could be concluded that there is a reciprocal influence during auditory and visual processing of emotional information depending on congruence [31], but the prioritization of one sensory modality over the other does not seem to follow a clear rule when the two modalities convey conflicting contents.

Many studies focused on the cerebral correlates of audio–visual integration and showed that different cerebral areas are implicated in this process: for example, Kreifelts and colleagues [32] found that the behavioral improvement during the simultaneous presentation of emotionally congruent bimodal stimuli correlated with an increased activation in the bilateral posterior superior temporal gyrus ([32]; see also [33], for a review) and in the right thalamus; other studies highlighted a left-hemispheric activation during bimodal processing, in particular in the middle temporal gyrus [34,35] and in the posterior superior temporal sulcus [36]. Jeong and colleagues [37] found that emotionally congruent audio–visual presentations enhanced the activity in auditory areas, whereas emotionally incongruent presentations enhanced the activity in face recognition areas, such as the fusiform gyrus. Ethofer and colleagues [38] have recently shown the importance of the orbitofrontal cortex in the mechanism of habituation to facial expressions and prosody, which highlights the role of this region as an important component of a system for emotional processing of faces and voices and as a neural interface among sensory areas. Finally, electrophysiological data demonstrated an early audio–visual crosstalk following stimulus presentation [39,34].

Another source of information about audio–visual neural correlates comes from studies on neurological patients. Hayakawa and colleagues [40] showed that a patient with amygdala and hippocampus lesions could not recognize fear from facial expressions, but was able to recognize them from prosodic and verbal stimuli, whereas a patient with a more extended lesion beyond the amygdala could not recognize fear expressions from prosodic and verbal stimuli, even if he was able to recognize them from facial stimuli [40].

Although audio–visual integration has been largely investigated, hemispheric lateralization in this field remains largely unexplored, even more so in the case of multisensory analysis in emotion perception. One of the possible sources of evidence consists in studying split-brain patients [41,42], individuals who have undergone the surgical resection of the corpus callosum (CC) as an extreme attempt to prevent the spread of epileptic seizures between the two hemispheres [43]. Importantly, comparisons among the performance of patients who have undergone different degrees of hemispheric disconnection (total or partial and, in the latter case, in different regions of the CC) provide us with a rare chance to study hemispheric competences [44]. Studies with callosotomized patients confirmed the right-hemispheric superiority in face processing [45], as well as the left-hemispheric superiority (REA) in dichotic listening ([46]; see [47], for a review). However the hemispheric superiority in emotion analysis remains controversial even as regards split-brain patients' results: Stone et al. [48] showed that both disconnected hemispheres could match equally well facial expressions to emotion words, but the left hemisphere performed poorly on a discrimination task. Làdavas