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Coordinated autonomic and respiratory responses evoked by alerting stimuli: Role of the midbrain colliculi

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ABSTRACT

Threatening stimuli trigger rapid and coordinated behavioral responses supported by cardiorespiratory changes. The midbrain colliculi can generate coordinated orienting or defensive behavioral responses, and it has been proposed that collicular neurons also generate appropriate cardiovascular and respiratory responses to support such behaviors. We have shown previously that under conditions where collicular neurons are disinhibited, coordinated cardiovascular, somatomotor and respiratory responses can be evoked independently of the cortex by auditory, visual and somatosensory stimuli. Here we report that these natural stimuli effectively increase inspiratory time most likely though phase switching. As a result the pattern of phrenic and sympathetic coupling is an inspiratory-related sympathoexcitation. We propose that blockade of tonic GABAergic input in the midbrain colliculi permits alerting stimuli to drive command neurons that generate coordinated cardiovascular, respiratory and motor outputs. The outputs of these command neurons likely interact with the central respiratory pattern generator, however the precise output pathways mediating the coordinated autonomic and respiratory responses remain to be determined.

1. Introduction

The acute alerting response to threatening stimuli consists of an integrated and stereotyped pattern of autonomic, respiratory and somatomotor changes that increases the probability of survival and is found in all species. Interestingly, the physiological responses seen in animals exposed to diverse environmental challenges include specific stereotyped changes. A sudden alerting stimulus, usually signaled by a visual, auditory or somatosensory input, immediately generates a behavioral response such as avoidance or flight depending on the intensity of the stimulus (Dampney et al., 2008; Kabir et al., 2010). The behavioral response is always accompanied by autonomic changes characterized by increases in blood pressure (BP), tachycardia, mydriasis, piloerection and cutaneous vasoconstriction (Hilton, 1982; Dampney et al., 2008). Respiratory changes of rapid onset, which consist of increases in respiratory rate and depth, are also observed in an alerting response (Blanchard and Blanchard, 1972; Kabir et al., 2010). The increase in arterial pressure provides perfusion of skeletal muscles priming them for activity, whereas, the increase in respiratory activity optimizes gas exchange to match increased activity or vigilance optimizing the fight/flight reaction (Dampney et al., 2008).

Previous studies have indicated that sites within the central nervous system such as the dorsomedial hypothalamus, periaqueductal grey (PAG), amygdala and the midbrain colliculi are involved in the generation of coordinated aversive responses to threatening stimuli (Dampney et al., 2013; Dampney, 2015). However, the pattern of the evoked responses vary greatly with the nature of the danger; depending upon whether the threat is present and requires immediate action, or simply enhanced and sustained vigilance (Blanchard et al., 1993).

2. Role of the midbrain colliculi in the alerting response

The superior colliculus (SC) is a layered region localized in the dorsal region of the midbrain. The superficial layers receive a direct innervation from the retina and an indirect one from the visual cortex, whereas the intermediate and deep layers receive auditory and somatosensory inputs (Dean et al., 1989). Electrical and chemical

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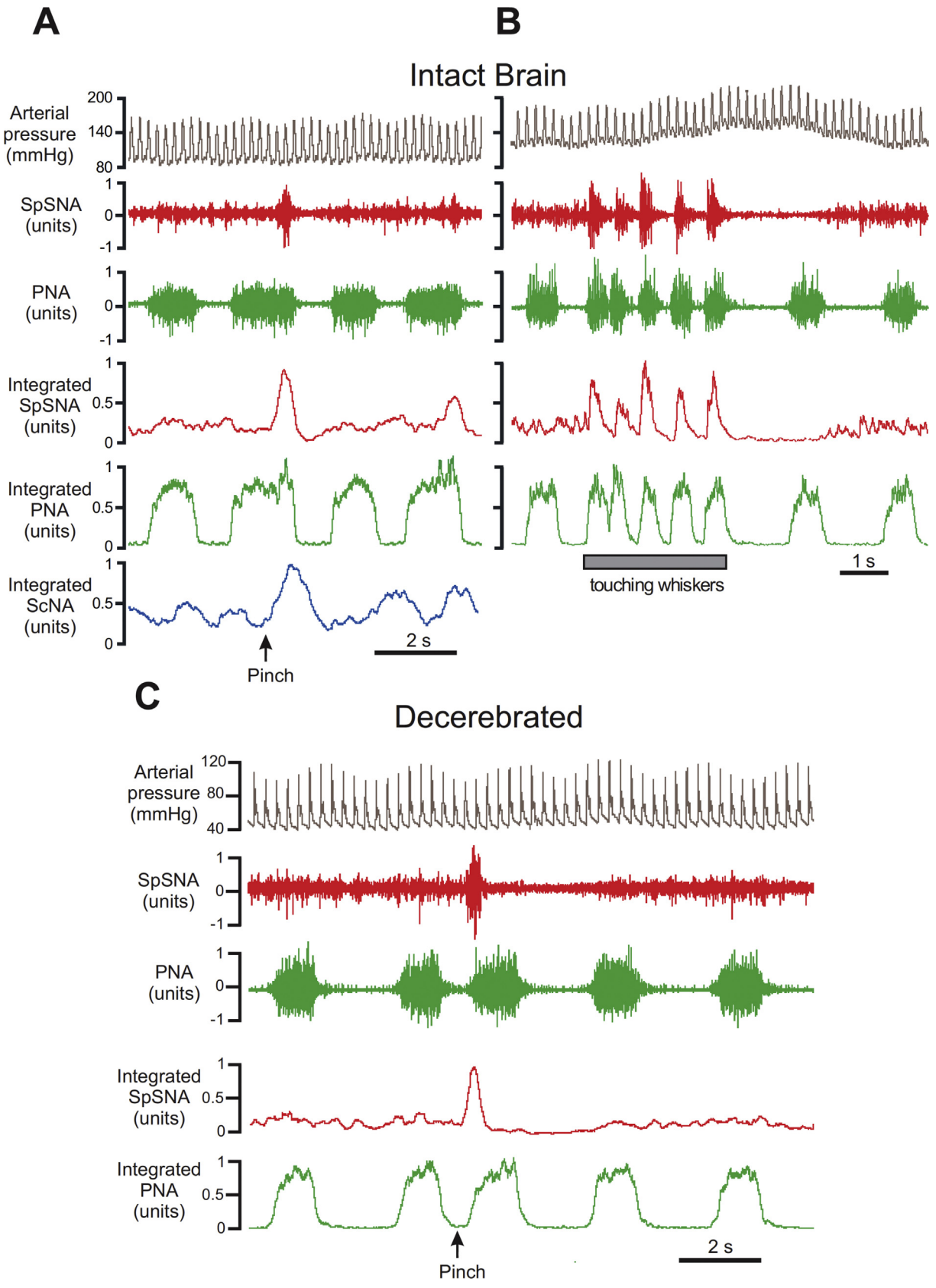

Fig. 1. Examples of recordings from two different experiments: intact brain and following decerebration. (A) Cardiovascular, respiratory and somatomotor responses evoked by pinch after microinjection of picrotoxin into the colliculus. (B) Cardiovascular, sympathetic and respiratory responses evoked by another sensory stimulus (touching whiskers) after microinjection of picrotoxin into the colliculus. (C) Cardiovascular and respiratory responses evoked by pinch after microinjection of bicuculline into the colliculus in a decerebrate preparation.