Short report

Electrophysiological evidence for crossed oligosynaptic trigemino-facial connections in normal man

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SUMMARY A crossed short latency component (R1) of the human blink reflex could be elicited in orbicularis oculi muscles to stimulation of the contralateral supraorbital nerve, when infraliminal conditioning stimuli were applied to various cutaneous afferents of the body (facial, upper and lower limbs). The crossed R1 responses appeared when the time interval between the conditioning and the test stimuli was of 30 to 40 ms, 50 to 65 ms and 95 to 110 ms for facial, upper and lower limbs afferents respectively. For the same time intervals, these conditioning volleys also exerted a facilitatory effect on the ipsilateral R1 responses. Furthermore, crossed R1 responses were also obtained during supraspinal facilitation induced by a voluntary contraction of the eyelids. These data show that crossed oligosynaptic trigemino-facial reflex connections exist in normal subjects, which become functional when adequate conditioning stimuli are available.

Electrical stimulation of supraorbital nerve results in a well known double trigemino-facial reflex discharge of EMG activity (R1 and R2) in the ipsilateral orbicularis oculi muscle and a single discharge (R2) in the contralateral muscle.[1–4] The early ipsilateral component (R1) is transmitted through an oligosynaptic arc in the pons.[5 6] The late bilateral component (R2) follows a long polysynaptic pathway travelling through the spinal nucleus of the trigeminal nerve.[6 7] Although direct anatomical connections between the trigeminal sensory nucleus and the contralateral facial nucleus have been described,[8] most authors agree on the strictly ipsilateral distribution of R1. However the occasional crossed character of this early response has been reported in both healthy subjects[9] and patients with post-facial palsy mass contractions.[10 11] The aim of the present study was to investigate whether these contralateral early responses (R1) are produced by abnormal synaptic connections or by existing synapses that are normally irresponsive to supraorbital nerve stimulation. In order to test the latter hypothesis, we used different electrophysiological techniques (sub and supraliminal conditioning stimulations of the blink reflex, voluntary contraction of the orbicularis oculi muscle) so as to obtain a facilitation of these putative synapses.

Subjects and methods

The experiments were carried out with eight unpaid healthy volunteers (four males, four females, 23 to 34 years old). They were carefully briefed of the aim and procedure of this study in order to avoid any element of surprise or of anxiety which are known to modify spinal reflectivity.[12 13] During the sessions they sat comfortably in an armchair, eyes gently closed, so as to obtain a state of good muscular relaxation.

Electrical stimulation of ipsi and contralateral supraorbital nerves as well as other segmental and heterosegmental cutaneous nerves, that is contralateral infraorbital and facial[14] nerves and cutaneous branches of upper and lower limb nerves (radial, median, ulnar, sural and musculocutaneous nerves) was achieved using a pair of surface electrodes placed on the skin above each nerve. The stimulus consisted of a single rectangular pulse of 0·2 ms duration delivered by a constant-current stimulator at a rate of 0·2 Hz. Reflex activities were recorded from the

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two orbicularis oculi muscles by means of surface electrodes placed on the degreased skin above the muscle in question. After amplification, the reflex responses were displayed in parallel on a storage oscilloscope (photographs and monitoring) and on a computer for an on-line analysis and quantification of the data.

The experimental procedure was defined as follows: The blink reflex test was evoked with an ipsilateral and/or a contralateral supraorbital nerve stimulation. This reflex was conditioned by previous infra or supraliminal stimulations using a classical excitability technique, that is, double shock with a variable inter-stimulus time interval (from 10 to 120 ms) between the conditioning and test stimuli. Each conditioning situation was delivered randomly and was preceded by control periods during which the test stimulus was only delivered (control responses). Finally, the effect of a slight voluntary contraction of the eyelids over a 5 minute period was studied during a contralateral supraorbital nerve stimulation.

When quantification of reflex activities was necessary, the amplitudes of the R1 test responses were converted into a percentage of the mean amplitude of the R1 control responses (100% representing the mean of 50 R1 control responses) in order to allow a comparison between several sessions for a same subject as well as for the whole group.

Results

EFFECTS OF SUBLIMINAL CONDITIONING AFFERENTS ON THE BLINK REFLEX RESPONSES ELICITED BY CONTRALATERAL SUPRAORBITAL NERVE STIMULATION

In all subjects, a crossed R1 response was obtained from the contralateral muscle (with respect to supraorbital nerve stimulation) when the time interval
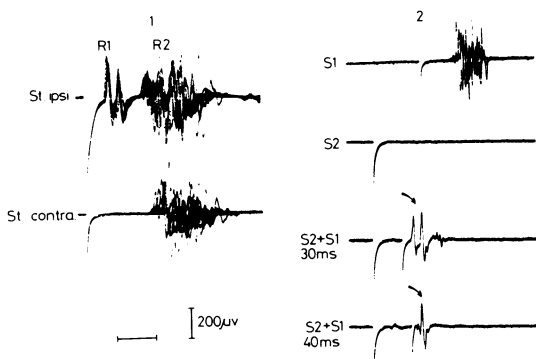
between the conditioning and test stimuli varied between 30 to 40 ms for segmental conditioning stimuli (fig 1) and between 50 to 65 ms and 95 to 110 ms for upper and lower limb conditioning afferents respectively. It should be noted that concomitantly the contralateral R2 test response was abolished (fig 1).

EFFECTS OF SUPRALIMINAL CONDITIONING AFFERENTS ON THE R1 TEST RESPONSE ELICITED BY IPSILATERAL SUPRAORBITAL NERVE STIMULATION

The segmental and heterosegmental conditioning stimuli produced an increase in the amplitude of the R1 test response. A maximal amplitude of R1 was obtained for an inter-stimulus time interval of 35 ms in the case of facial conditioning afferents and of 60 ms and 100 ms for upper and lower limb conditioning stimulations respectively. These time intervals are coherent with a polysynaptic facilitatory effect from segmental and intersegmental origin.[5]

EFFECTS OF VOLUNTARY CONTRACTION OF THE EYELIDS ON THE BLINK REFLEX RESPONSES ELICITED BY CONTRALATERAL SUPRAORBITAL NERVE STIMULATION

As it can be seen from fig 2, crossed R1 responses appeared in the contralateral orbicularis oculi muscle (with respect to supraorbital nerve stimulation) whereas the amplitude of the contralateral R2 component was increased. As far as we could extract the
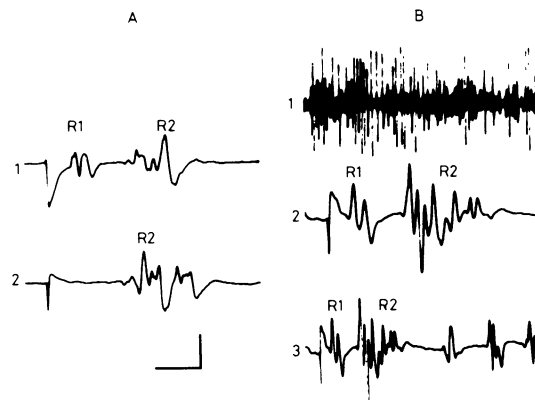

Fig 1 *(1) Blink reflex responses from right orbicularis oculi muscle elicited by ipsilateral (upper) and contralateral (lower) supraorbital nerve stimulation. (2) Same subject as in (1). S1 : R2 responses elicited by contralateral supraorbital nerve stimulation. S2 : infraliminal stimulation of the contralateral infraorbital nerve. S2 + S1 : both stimuli are applied with a time interval of 30 and 40 ms. Note that the best crossed R1 response is obtained with a 30 ms delay. Time base : 20 ms (in 1); 40 ms (in 2).*

Fig 2 *(A) Usual blink reflex responses from right (1) and left (2) orbicularis oculi muscles elicited by a right supraorbital nerve stimulation. (B) Same subject. Effect of a voluntary contraction of the eyelids on the left blink reflex responses (right supraorbital nerve stimulation). (1) EMG activity during the contraction. (2) and (3) reflex responses (crossed R1 and R2) observed during the contraction. Calibration: horizontal: 20 ms in A and in B 2, 40 ms in B 3, 200 ms in B 1; vertical: 200 μV.*

blink components from the tonic EMG activity, the crossed R1 responses became larger and larger as a function of the strength of eyelids contraction. These crossed responses were observed systematically for each stimulation in all subjects when the voluntary contraction was effective and maintained.

Discussion

The findings show that a crossed (contralateral) R1 response can be easily obtained in normal subjects during some conditioning stimulations. These conditioning inputs exert a facilitatory effect upon the R1 reflex pathway crossing the midline of the central nervous system. This effect was further analysed using excitability curves of the R1 component. In all cases, the inter-stimulus time interval producing a maximal increase in the R1 amplitude was found to be the same as that which evoked the appearance of the crossed R1 response (fig 1) (either segmentally or heterosegmentally). These data suggest that the same facilitating mechanism could be involved in these two phenomena. Moreover, it is of interest that this time interval corresponded also to the inhibition of the R2 component (fig 1). These results are in agreement with others which have shown that the ipsilateral blink reflex responses were easily modified (facilitation of R1, major depression of R2) either by segmental or heterosegmental conditioning afferents.[15] [16] These authors stated that the depression of R2 was not related to the after-hyperpolarization period[17] of the facial motoneurons but rather depended on a local inhibitory synaptic mechanism involving a convergence phenomenon between the polysynaptic afferents on the same interneuronal pool. This would suggest that the appearance of the crossed R1 as well as the facilitation of the ipsilateral R1 responses (excitability curves) are always correlated with a simultaneous R2 depression. However, this is not supported by our findings which show that a physiological pyramidal facilitation (that is voluntary contraction of the eyelids) produced an increase of the normal blink components (R1 and R2) parallel with the appearance of a crossed R1 response (fig 2). This discrepancy can be explained by the non-natural (that is, non-fonctional) aspect of the electrical conditioning stimulus when studying excitability curves, while a voluntary contraction of the eyelids is more functionally related and involves massive facilitating inputs on the two facial motor nuclei.

Thus, it is tempting to conclude that the contralateral R1 response exists potentially in normal subjects but is not elicited when testing the blink reflex with the classical method, that is, with a unilateral supraorbital nerve stimulation in relaxed subjects with "eyes gently closed" as currently described in literature. The appearance of this crossed R1 response would depend on the existence or not of a background activity in the facial motoneurons. This idea could easily explain the existence of crossed R1 responses observed in patients with motor disorders which result in facial hyperactivity, such as median spasm or post-facial-palsy mass contractions. However, the mechanism by which the crossed R1 response needs a conditioning stimulus to be elicited remains unclear.

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