Research article

Muscular effort increases hand-blink reflex magnitude

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A B S T R A C T

Defensive motor responses elicited by sudden environmental stimuli are finely modulated by their behavioural relevance to maximise the organism’s survival. One such response, the blink reflex evoked by intense electrical stimulation of the median nerve (Hand-Blink Reflex; HBR), has been extensively used to derive fine-grained maps of defensive peripersonal space. However, as other subcortical reflexes, the HBR might also be modulated by lower-level factors that do not bear direct relevance to the defensive value of blinking, thus posing methodological and interpretive problems. Here, we tested whether HBR magnitude is affected by the muscular effort present when holding the hand in certain postures. We found that HBR magnitude increases with muscular effort, an effect most likely mediated by the increased corticospinal drive. However, we found strong evidence that this effect is substantially smaller than the well-known effect of eye-hand proximity on HBR magnitude. Nonetheless, care should be taken in future experiments to avoid erroneous interpretations of the effects of muscular effort as indicators of behaviour relevance.

1. Introduction

The eye blink in response to intense environmental stimuli is a prototypical defensive response to potential threats to the body [1], and it is typically evoked by a variety of somatosensory and non-somatosensory stimuli. When elicited by intense somatosensory stimuli delivered to the median nerve, the blink reflex is referred to as the hand-blink reflex (HBR) [2].

After the first descriptions of the physiological properties of the HBR in clinical neurophysiology in the late ‘90s [2–4], the recording of the HBR has recently gained traction to investigate the spatial properties of the brain’s representation of environmental threats [5–8]. Indeed, despite being entirely mediated by a subcortical circuit, we have shown that the HBR magnitude is enhanced when the stimulated hand is located closer to the face [5]. Furthermore, the magnitude of the HBR at particular points in space is affected by contextual factors such as the estimated defensive value of physical barriers [5], the anxiety trait [9], gravitational cues [10], motion of the stimulated hand [11,12], interpersonal interactions [8], chronic pain conditions [13], and blindness [14]. Given that at least some of these factors reflect cortical processing, it is probable that these effects are enacted by a cortical modulation on the excitability of the brainstem circuits subserving the HBR [5,15], and thus represent behaviourally relevant modulations of a response aiming to minimise damage to the body [16].

By exploring the HBR modulation by a large number of spatial locations of the stimulated hand in egocentric coordinates, we have characterized the fine-grained spatial properties of what we labeled the defensive peripersonal space (DPPS) surrounding the face [5,6]. This has furthered the understanding of how the position of potentially noxious stimuli affects the relevance of defensive avoidance responses [16].

However, in some of these experiments we have anecdotally observed that the HBR magnitude appeared to be increased in postures that require considerable effort to be reached and maintained. This idea is consistent with the well-known facilitation of subcortical reflexes when organisms exert a muscular effort, such as during the Jendrassik manoeuvre [17]. Therefore, it is possible that the HBR magnitude is partially determined by the tonic corticospinal drive required to place and keep the hand in a particular position. Clarifying this possibility is important, since such an increase in HBR magnitude would not reflect the cortex’s influence on a defensive response, making the reverse inference between HBR magnitude and defensive behavioural relevance of a stimulus less likely to be correct (see Box 1 in [18]).

Here, we empirically assessed whether such an effect of effort on the HBR exists.

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2. Materials and method

2.1. Participants

We analysed data from 14 participants (9 women, mean age 24.8 ± 5.0 yrs) to test whether the effort required to keep the hand in certain stimulation positions contributes to the HBR magnitude. To identify these HBR ‘responders’ [2,3,5], we collected data from 19 participants. Only those showing a HBR magnitude more than two standard deviations above pre-stimulus EMG activity in more than 40% of trials were considered to be HBR responders. Hence, 74% of subjects were HBR responders. This percentage is consistent with previous reports [5,9,15]. Participants gave written, informed consent before taking part in the study. The study was approved by the local ethics committee.

2.2. Stimulation

Participants were seated in a comfortable chair. Somatosensory stimuli consisted of constant-current squared pulses generated by an electrical stimulator (DS7A, Digitimer). Stimuli were delivered using a surface bipolar electrode placed on the right median nerve at the wrist. Stimulus duration was 200 μs, and the interval between successive stimuli was 30 s. In each participant, we first determined the stimulus intensity able to elicit a well-defined and stable blink reflex in response to electrical stimulation of the median nerve at the wrist (mean intensity 36.8 ± 11.3 mA). This was achieved by increasing the stimulus intensity until a clear HBR was observed in three consecutive trials, or the participant refused a further increase of stimulus intensity [2,3].

EMG activity was recorded from the orbicularis oculi muscle bilaterally, using pairs of surface electrodes with the active electrode over the lower eyelid and the reference electrode a few centimeters laterally to the outer canthus. Signals were amplified and digitized at a sampling rate of 8,192 Hz, and stored for off-line analysis.

2.3. Experimental Procedures

Somatosensory stimuli were delivered in four different conditions (as in Fig. 1, below). In Condition 1, the hand was resting on a desk in front of the participant with the palm facing upwards (position ‘Far’, approximately 60 cm from the face). In Condition 2, the hand was in the exact same ‘Far’ position, but a 1 kg weight was placed on the palm. Condition 3 was identical to Condition 2 (hand in position ‘Far’, with a weight on it), but participants were instructed to raise their entire forearm ~1 cm off the desk whilst holding the weight – a posture requiring considerable effort to keep the hand in position. In Condition 4 the hand was in the ‘Near’ position, i.e. at eye-height, approximately 4 cm in front of the face.

We assumed the effort required to hold the hand in a given position is roughly proportional to the moment of force of the arm on the shoulder. We also assumed that the arm weighs 4 kg, has equal radius and density along its length, and hence that the weight of the arm acts at its centre of mass. We finally assumed that the arm is 70 cm long, that it is completely extended in the Condition 1, and that the shoulder is 10 cm behind the face. Therefore, the moment of force at the shoulder in Conditions 1 and 2 is approximately 0 Nm, as the arm is resting on the table (although the muscular effort in Condition 2 is probably slightly higher than in Condition 1 due to the need to stabilise and hold on to the 1 kg weight). In Condition 3, the moment of force is approximately 21 Nm (9.81 N/kg x (0.35 m x 4 kg + 0.7 m x 1 kg)). In Condition 4, the moment of force is approximately 3 Nm (0.07 m x 4 kg x 9.81 N/kg).

2.4. Data analyses and statistics

EMG signals from each participant were high-pass filtered (55 Hz) and full-wave rectified. The HBR magnitude was calculated as the area-under-curve (AUC) of each single-trial response, separately for each recording site. AUCs were first averaged across ipsilateral and contralateral recording sites and then across trials within each Condition. Finally, AUCs were normalized for each subject as Z-scores.

To investigate whether there was a difference in HBR magnitude between conditions, we performed a one-way repeated-measures ANOVA with four levels – one for each condition. We performed Mauchly’s test of sphericity to check whether correlations should be made to the results. We subsequently performed false-detection-rate corrected post-hoc paired t-tests between all conditions in order to identify any source of difference in HBR magnitudes.

3. Results

The repeated measures ANOVA showed strong evidence for a difference in HBR magnitudes between experimental conditions (F = 92.756, p = 2.62*10−4, Sphericity not violated; p = 0.0786).
Post-hoc, FDR-corrected, paired t-tests between conditions showed strong evidence that the HBR magnitude was larger in Condition 4 (i.e. when the hand was near the face) than in all other three Conditions (i.e. when the hand was far from the face). These results of previously published experiments might have been confounded by the e
erfects of gravity on the brain’s estimate of the probability of the threat (represented by the somatosensory stimulus eliciting the reflex) will harm the body: when stimuli are above the body, they are more likely to move downwards to interact with, and thus harm the body. A follow up experiment tested this interpretation explicitly, and, importantly, for the first time controlled for the e
erfect of experimenters holding the participants’ arms in place [10]. In doing so, the participants’ muscular effort necessary for holding the used hand postures was at least substantially reduced. While this study still revealed an increased HBR magnitude when the stimulated hand was above eye level as compared to when it was at the same distance below eye level, the increase was smaller [10]. Thus, the discrepancy in size of the effect of gravity might in fact be due to effort. As is often the case however, other explanations cannot be excluded. For example, the cortex might rely on muscular activation in order to effectively update its estimate of the hand’s position. If this were the case, the decrease in effort caused by experimenters holding participants’ arms might have coincided with a decrease in proprioceptive awareness, which in turn resulted in the observed difference. This would mean that the brain might use muscular activation as a gravitational cue when it updates the DPPS. Of course, Occam’s Razor makes this option the least likely.

Thus, the reported results indicate that future HBR experiments should be designed taking this issue into account. For example, the effort required to hold the arm raised and outstretched is greater than that required to hold it raised but near the body, and so the effect of effort scales inversely with distance. Therefore, if one were to compare the HBR proximity effect (as done in [9]) between when the arm is lifted by the participant and when the arm is held in place by the experimenter, one might erroneously conclude that the defensive field mapped out by the HBR has changed. Hence, while the effect of effort is relatively small, experiments exploiting small differences in HBR magnitude should control for it, either by supporting the arm, or by matching effort across tested conditions.

In more general terms, these results can serve as a reminder that even responses which are very reliably modulated by high level factors, and therefore clearly seem to have a particular interpretation, can still be modulated by confounding factors and lead to erroneous conclusions. Reverse inference, thus, remains a dangerous game [18].

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