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This meta-analysis of 26 reports published between 1978 and 2010 tests an unusual hypothesis: for stimuli of two or more types that are presented in an order designed to be unpredictable and that produce different post-stimulus physiological activity, the direction of pre-stimulus physiological activity reflects the direction of post-stimulus physiological activity, resulting in an unexplained anticipatory effect. The reports we examined used one of two paradigms: (1) randomly ordered presentations of arousing vs. neutral stimuli, or (2) guessing tasks with feedback (correct vs. incorrect). Dependent variables included: electrodermal activity, heart rate, blood volume, pupil dilation, electroencephalographic activity, and blood oxygenation level dependent (BOLD) activity. To avoid including data hand-picked from multiple different analyses, no post hoc experiments were considered. The results reveal a significant overall effect with a small effect size [fixed effect: overall ES = 0.21, 95% CI = 0.15–0.27, $z = 6.9$, $p < 2.7 \times 10^{-12}$; random effects: overall (weighted) ES = 0.21, 95% CI = 0.13–0.29, $z = 5.3$, $p < 5.7 \times 10^{-8}$]. Higher quality experiments produced a quantitatively larger effect size and a greater level of significance than lower quality studies. The number of contrary unpublished reports that would be necessary to reduce the level of significance to chance ($p > 0.05$) was conservatively calculated to be 87 reports. We explore alternative explanations and examine the potential linkage between this unexplained anticipatory activity and other results demonstrating meaningful pre-stimulus activity preceding behaviorally relevant events. We conclude that to further examine this currently unexplained anticipatory activity, multiple replications arising from different laboratories using the same methods are necessary. The cause of this anticipatory activity, which undoubtedly lies within the realm of natural physical processes (as opposed to supernatural or paranormal ones), remains to be determined.

Introduction

Predicting the future is an essential function of the nervous system. If we see dark clouds and smell a certain scent in the air, we predict that rain is likely to fall. If we hear a dog bark, we predict that we will see a dog nearby. These everyday predictions are based on experience (e.g., memory) and perceptual cues. If even without experience and perceptual cues we could somehow prepare for important imminent events by activating the sympathetic nervous system prior to such events, this skill would of course be highly adaptive. More than forty experiments published over the past 32 years examine the claim that human physiology predicts future important or arousing events, even though we do not currently understand how such a thing

could be accomplished. This meta-analysis examines a subset of these experiments allowing us to test the hypothesis that seemingly without experience and perceptual cues, human physiological measures anticipate what seem to be unpredictable future events by deviating from a baseline before an event occurs, in the same direction that they will continue to deviate after that event occurs. This is a controversial but important hypothesis. Thus, although there is no known mechanism for the effect reported in such studies, the implications of such an effect are far-reaching enough to justify a careful meta-analysis.

The studies we include in this meta-analysis make direct comparisons between pre-stimulus physiological activity measures using paradigms that produce a contrast in post-stimulus physiological activity between responses to stimuli from different categories. Two paradigms are used: (1) randomly ordered presentations of arousing vs. neutral stimuli, or (2) guessing tasks for which the stimulus is the feedback about the participant's guess (correct vs. incorrect). In arousing vs. neutral stimulus paradigms, participants are shown, for example, a randomly intermixed series of violent and emotionally neutral photographs on each trial, and there is no a priori way to predict which type of stimulus will be viewed in the upcoming trial. In guessing tasks, on each trial participants are asked to predict randomly selected future stimuli (such as which of four cards will appear on the screen) and once they have made their prediction, they then view the target stimulus, which becomes feedback for the participant. Because participants perform at chance on these tasks, guessing tasks generally create a random distribution of events producing separable physiological responses that reflect brief states of positive arousal (following feedback indicating a correct guess) and negative and/or lower arousal (following feedback indicating an incorrect guess). Regardless of the paradigm, physiological measures [skin conductance, heart rate, blood volume, respiration, electroencephalographic (EEG) activity, pupil dilation, blink rate, and/or blood oxygenation level dependent (BOLD) responses] are recorded throughout the session, and stimulus times are usually marked in the physiological trace itself. These continuous data are later portioned according to a pre-determined "anticipatory period" designated for analysis (generally 0.5–10 s preceding stimulus presentation, depending on the temporal sensitivity of the physiological measure and the inter-trial interval). The portioned data are marked according to the type of stimuli they precede (arousing or neutral stimuli for the arousing vs. neutral paradigm, feedback indicating correct or incorrect guesses for the guessing paradigm). Pre-stimulus data are then compared across stimulus types.

It has been known for some time that arousing and neutral stimuli produce somewhat different post-stimulus physiological responses in humans (Lang et al., 1993, 1998; Cuthbert et al., 1996, 2000). However, what is remarkable is that many of the studies examined here make the claim that, for instance, the same physiological measure that yields a differential post-stimulus response to two stimulus classes also yields a differential pre-stimulus response to those same stimulus classes, prior even to the random selection of the stimulus type by the computer. Authors of these studies often refer to the effect as presentiment (sensing an event before it occurs) or unexplained anticipatory activity; we favor the latter terminology as it describes the phenomenon without implying that the effect truly reflects a reversal of the usual forward causality.

The primary value of this meta-analysis is that it tests a hypothesis that is different from those

examined in most of the studies included in it. For the included studies, the hypotheses were, for the most part, bidirectional – namely, that the data would reveal a significant difference between physiological activity preceding two (or more) seemingly unpredictable stimulus types, regardless of the direction of that difference. A meta-analysis of these data would certainly be significant, as any deviation between the two physiological activity measures would produce a positive effect size (ES), in favor of a hypothesis that there is any difference between the measures. In contrast, adopting a more conservative approach, ours is a directional hypothesis: for paradigms producing post-stimulus effects differing between two or more stimulus types, and with randomized and theoretically unpredictable stimulus orders, the pre-stimulus difference between those same stimulus categories will have the same sign as the post-stimulus difference. In other words, we use meta-analytic techniques to test the hypothesis that the direction of pre-stimulus activity is predictive of the direction of post-stimulus activity, even when the stimulus category itself seems to be unpredictable1. To our knowledge, this is the first meta-analysis examining this phenomenon. {jcomments off}FULL TEXT PDF