# Does Psychophysiological Predictive Anticipatory Activity Predict Real or Future Probable Events?

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**Background:** The possibility of predicting random future events before any sensory clues by using human physiology as a dependent variable has been supported by the meta-analysis of Moss-bridge et al. (2012)[1] and recent findings by Tressoldi et al. (2011 and 2013)[2,3] and Mossbridge et al. (2014)[4] defined this phenomenon predictive anticipatory activity (PAA).

**Aim of the study:** From a theoretical point of view, one interesting question is whether PAA is related to the effective, real future presentation of these stimuli or whether it is related only to the probability of their presentation.

**Methods:** This hypothesis was tested with four experiments, two using heart rate and two using pupil dilation as dependent variables.

**Results:** In all four experiments, both a neutral stimulus and a potentially threatening stimulus were predicted 7–10% above chance, independently from whether the predicted threatening stimulus was presented or not.

**Conclusion:** These findings are discussed with reference to the "grandfather paradox," and some candidate explanations for this phenomena are presented.

**Keywords:** Random events, anticipation, prediction, pupil dilation, heart rate

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## INTRODUCTION

wThere is accumulating evidence that our nervous systems, the autonomic and the neurological, react to unpredictable (randomly presented) stimulation 3–10 seconds before they are triggered by a sensorial (visual or acoustic) stimulation. This anticipation is revealed by analyzing how psychophysiological signals change in relationship to the characteristics of future stimulations, for example, whether heart rate is enhanced before a future emotional stimulation compared to a non-emotional one. The anticipatory responses are analyzed averaging the psychophysiological responses, i.e., heart rate, skin conductance level, electroencephalography (EEG), etc., of all trials in order to extract the signal from the noise. A prototypical response is presented in Figure 1.

The possibility of predicting random future events using human physiology as dependent variable, before any sensory clues, is now supported by the meta-analysis of Mossbridge et al.,[1] reporting an estimated effect size of 0.21, 95% confidence interval (CI) = 0.13–0.29. This phenomenon, was defined predictive anticipatory activity (PAA), and its possible mechanisms, the theoretical implications, and its potential practical applications are discussed by Mossbridge et al.[4]

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The interpretation of this apparent violation of time-symmetry is still under theoretical and empirical investigation. Given the aim of this article, we will discuss them only briefly in the discussion.

Tressoldi et al.[2,3] started a line of research aimed at using PAA to predict the category (neutral vs. emotional) of each stimulus presented randomly, at the level of single trials. In these experiments, there were two main methodological differences with respect to the typical procedure used to study the PAA. The first is that PAA is not averaged among all the trials of the experiment but used at the level of single trial to predict the category of the future events. It is clear that this implies a higher difficulty extracting the signal from the noise. The second main difference is that the aim of this line of research was not only to see whether the PAA mirrored the physiological reactions observed after the stimuli presentation but also to see whether the accuracy of these predictions was above the expected chance, for example, 50% when there are two categories to predict. A strong demonstration that PAA can predict future random events well above the chance will open the door to implement practical applications.

In studies by Tressoldi et al.,[2,3] it was shown that pupil dilation (PD) PAA predicted the random presentation of a neutral (a neutral sound or a smile) or an alerting stimulus (an alerting sound or an image of a gun associated with an acoustic shot) 6–10% above the chance expectation of 50%.

One interesting question is whether this PAA is related to the effective, real future presentation of these stimuli or whether it is related only to the probability of their presentation.


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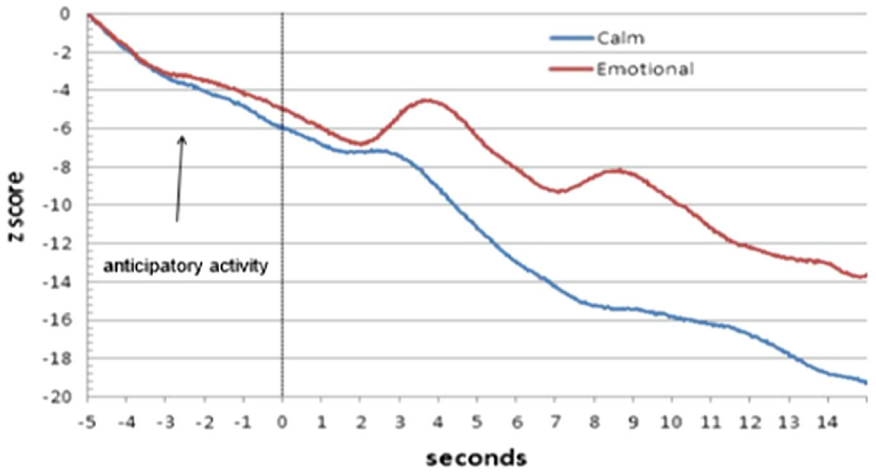


**Figure 1.** Example of a predictive anticipatory response related to two future events of different emotional content.

From a philosophical point of view, this problem is known as the "bilking argument" first introduced by Max Black.[5] The "bilking argument" states that if B is earlier than A, and let B be the alleged effect of A, if we assume that A causes B even though A is later than B, it is possible, in principle, to intervene in the course of events and prohibit A from occurring. But if this is the case, A cannot be the cause of B; hence, we cannot have backward causation or anticipatory prediction. Another name for this problem is "grandfather paradox"[6] described as follows: "*The time traveller goes back in time and kills his grandfather before his grandfather meets his grandmother. As a result, the time traveller is never born. But, if he was never born, then he is unable to travel through time and kill his grandfather, which means the traveller would then be born after all, and so on.*"

One solution to this conundrum is to devise experiments where the predicted stimulus is not presented but skipped or deleted. If the predicted event is skipped, it cannot exert any backward effect and hence the prediction accuracy should be at chance. If, however, the prediction accuracy is above chance, it is necessary to explain which sort of information can be used to predict an event that never happened. We postpone the discussion of this problem to the end of the presentation of the results of all four experiments.

## EXPERIMENTS 1 AND 2

The first two experiments are conceptual replications of studies by Tressoldi et al.,[2,3] using heart rate (HR) as PAA, instead of PD. In the first experiment, all future random events will be presented. In the second one, predicted alarming events will be skipped.

### Method

***Participants.*** Estimating an effect size of approximately 0.30 as observed in Tressoldi et al.,[2,3] to achieve a statistical power above 0.80, setting $\alpha = 0.05$, an opportunity sample of 100 students and personnel from Padova University[7] were recruited by a research assistant to participate in an experiment on a gambling task. The final sample comprised 28 males and 72 females, with age ranging from 23 to 35 years. Their participation was compensated with €5.

***Ethics statement.*** Participation inclusion followed the ethics guidelines in accordance with the Helsinki Declaration, and the study was approved by the Ethics Committee of Dipartimento di Psicologia Generale, the hosting institution. Before taking part in the experiment, each participant provided written consent after reading a brief description of the experiment.

***Apparatus and procedure.*** HR was detected by a photoplethysmograph connected to the index finger of the left hand.[8] The signal was subsequently conveyed to a Pulse Monitor 701 and to a Metex 3850 D digital multimeter and fed to a PC for online data acquisition. The software for HR data acquisition, visualization, and its connection with the presentation of the two sounds was developed by the two coauthors, M.M. and L.S., in E-Prime™ v.2.0. Heart rate per minute was automatically estimated using the formula *P* (pulse) = 60,000 ms/inter beat interval (IBI).

The two sounds (available in Ref. 9) were chosen from the International Affective Digitised Sounds (IADS) collection,[10,11] selected to trigger an alert or a neutral reaction.

The procedure comprised two phases, a preliminary and an experimental one. The preliminary phase was devised only to familiarize the participants with the procedure. Participants were required to sit in a comfortable chair in a light- and sound-attenuated lab, facing a PC monitor. After they had been connected with the photoplethysmograph, they were instructed not to move their body, breathe regularly avoiding deep breaths, wear the headphones (model Inno Hit SH-154), and control on the PC monitor if their HR proceeded regularly. When the research assistant was certain that the HR was stabilized, that is, the HR values varied smoothly without peaks, he started the software that controlled the random presentation of the two sounds after the participant pressed the central key of a response-box (Figure S3). The session ended after the presentation of the two sounds 10 times each. The choice to use a fixed number of data instead