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# Heart Rate Differences between Targets and Nontargets in Intuitive Tasks[1]

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**Abstract**—This study reports the results of one experiment and a replication, aimed at investigating heart rate changes related to a purely intuitive task. In each experiment, 12 subjects were required to guess which of four pictures presented in sequence for about 10 s was the target. Each subject performed 20 trials. In each trial, the target was automatically selected using a pseudorandom algorithm. The heart rate was recorded during the picture presentation. In the first experiment, a statistically significant heart rate increment associated with targets with respect to nontargets was observed. The replication experiment with 12 new subjects confirmed the data obtained in the main experiment. These findings support the hypothesis that heart rate is related not only to conscious but also to unconscious cognitive activity such as that involved in intuitive tasks, giving convergent evidence for the models describing human intuitive cognitive activity as a double, partially independent information processing system.

Cognitive activity induces changes not only at the cortical level but also at the peripheral (cardiac, skin conductance, etc.) level. This relationship is firmly established not only for cognitive tasks involving emotional stimuli [1–3] but also even if tasks are emotion-free. Research on the relationship between neuropsychophysiological variables and cognitive tasks has a relatively long tradition. Regarding heart rate, the psychophysiological variable used in the present investigation, we can recall the pioneering contribution of Graham and Clifton [4] investigating the change in heart rate as a component of the orienting response, followed by the investigation by many other authors of different aspects of cognition such as attention [5], stimulus significance [6], self-induced thoughts [7], goal difficulty [8], and so on.

Among cognitive tasks, those requiring intuition are far less investigated. The notion of intuition varies among authors and fields of investigation such as psychology, neuroscience, and philosophy. The definition we will adopt is "knowing without being able to explain how we know" [9, 10]. Baylor [11] describes intuitive thinking as a cognitive activity proceeding automatically, interpreting immediately the situation it is facing. Stanovich and West [12] labeled the cognitive processes of intuition and reasoning as System 1 and System 2. The operations of System 1 are fast, automatic, effortless, associative, and difficult to control or modify. The operations of System 2, on the contrary, are slower, serial, effortful, and deliberately controlled. Intuitive cognitive activity is not episodic but is probably the cognitive process most frequently used in real life when it is necessary to solve social, economic, or practical problematic situations with time pressure. Although it is relevant, the scientific research on intuition is not very rich in either the cognitive or the neurophysiological field. It is worth mentioning the review by Lieberman [13], who proposes a link between implicit learning and social cognition, suggesting a common neural substrate, but empirical investigations remain lacking.

The present investigation took its inspiration from the findings and methodology of Bechara *et al.* [14, 15]. These authors revealed that skin resistance varied according to a positive or negative decision in a gambling task, well before subjects could discover and explain the rule governing the payoff.

Research has shown that gamblers exhibit increases in physiological arousal, heart rate included, when participating or even imagining that they are participating in gambling [16–18].

The possibility that physiological responses can convey information before subjects experience conscious awareness is an interesting line of investigation.

With a first exploratory experiment followed by a confirmatory one, we aimed at exploring the possibility that heart rate responses differ according to the category of the targets before subjects consciously possess this information. In contrast to Bechara *et al.* [14, 15], who used a gambling task with an underlying rule, we devised a simple game whose solution required "pure" intuition, that is, a decision that could not rely on implicit learning or personal expertise. To prevent any possibility of discovery of the rule underlying the task, the targets were chosen by an automated random algo-

[1] This article was submitted by the authors in English.

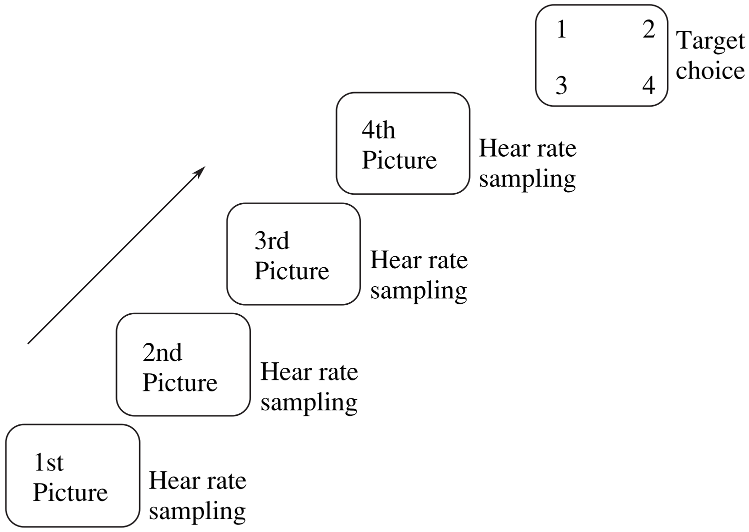


**Fig. 1.** Sequence of events for each trial.

rithm. As far as we know, this investigation represents the first such attempt. Our main hypothesis was simple: Can we observe an anticipatory heart rate difference between targets and nontargets before subjects can acquire this information explicitly?

## METHODS

**Experiment 1.** The participants were 12 subjects, 5 males and 7 females, mean age 25.5 years (range, 24–45), who were mainly people attending the university facilities. They were invited by a research assistant to participate in a computerized guessing task. Their participation was reimbursed with ¤3.

Participants sat comfortably in a chair in a soundproof laboratory facing a monitor. They were instructed not to move the index finger of their left hand, connected to an apparatus detecting their heart rate. They were invited to relax until an acoustic signal indicated that the trial was going to start. They were informed of the sequence of events in each trial and instructed to perform at their best. All were informed that targets would be selected by a random procedure and were told not to try to discover the underlying rules but to use their intuition.

Each trial consisted of a serial presentation of four emotionally neutral pictures (landscapes, animals, monuments) for about 10 s, the time necessary to collect ten heart rate data, followed by the simultaneous presentation of all four pictures for the choice of the target by the participant (Fig. 1). The target was chosen by a mouse click under the selected picture. Immediately after, the real target was indicated to inform the participant about the accuracy of his or her choice.

The pictures changed for each trial and were emotionally neutral images, such as landscapes, plants, flowers, or portraits. Their degree of emotionality was measured by asking ten independent judges to rate each picture on a ten-point scale from 0 (no emotion) to 10 (a high level of emotion). The mean score was 1.5, $SD = 0.5$.

The target was chosen from among the four pictures by an automatic randomization procedure before their simultaneous presentation on the PC screen. The randomization procedure, written in C++ for these experiments, returns a random number within the range 1–4 (corresponding to the four pictures) after initialization with a random value obtained from the system clock.

Data acquisition and apparatus functioning were continuously monitored by a research assistant with his or her back to the participant. Owing to the automation of the target selection, the assistant could not suggest anything to the subject.

The experiment ended after 20 trials.

### *Heart Rate Sampling*

During each picture presentation, ten heart rate samples were collected. Heart rate per minute was automatically estimated using the formula $P$ (pulse) = 60000 ms/IBI (interbeat interval). The heart rate monitor was connected by the PC parallel port with the computer for data acquisition converting the analog signal to digital form. The software for picture presentation and heart rate data acquisition was original and devised for these experiments [19]. Briefly, the apparatus for heart rate acquisition consisted of an optoelectronic sensor for a photoplethysmographic measurement by infrared light applied to the index finger of the left hand. 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.

If the research assistant noticed some artifacts during the experiment (for example, anomalous heart rate registrations or apparatus malfunctioning), the task was interrupted and started again.

### *Data Analysis*

The initial 800 data of each participant (10 heart rate data × 4 pictures × 20 trials) were reduced to 400 (200 for targets and 200 for nontargets) by collapsing the data related to nontargets. In order to have a statistical power above 0.80 with the expectation of a small difference between targets and nontargets, we added the 400 data of each subject instead of using their means. A simple paired *t*-test on the total 2400 data was used to compare heart rate related to targets and nontargets. Although from the studies on gambling presented in the introduction we expected a heart rate increase, for this first experiment we kept a two-sided probability given its exploratory nature.

## RESULTS AND DISCUSSION

### *Heart Rate*

The overall heart rate raw difference of 0.59 (C.I. 95% ± 0.48) between targets and nontargets was statistically significant, $t(2399) = -2.42$, $p = 0.015$, effect size $d = -0.043$ [20]. To better control the reliability of this result, we implemented a bootstrap analysis[1] [21] with the Simstat™ software [22] using 1000 resamples. The obtained result was $t(2399) = -2.41$ (C.I. 95% ± 2.09).

### *Hits*

The mean of targets correctly identified by the 12 participants was, as expected, close to the chance level (corresponding to 5), $M = 4.85$; $SD = 1.23$. Given this low number, we decided to analyze all the data related to targets independently of their correct or wrong identification.

The comparison of target and nontarget heart rates reveals a robust statistically significant difference. Before proceeding with the interpretation of this result, we wanted be sure that it was not a consequence of statistical artifacts. We thus planned a new identical experiment with 12 new subjects to confirm the findings of the first experiment.

[1] Bootstrap simulation is a resampling technique whereby initial samples are treated as if they constitute the population under study and is particularly useful for analyzing the autocorrelated time series data sets generated in psychophysiological experiments. By replicating those data an infinite number of times, we then draw at random from that population a large number of samples, each the same size as the original sample. By computing, for every bootstrap sample, a statistical estimator of interest (such as a mean, a correlation, or a *t*-test between two variables), we can use this resampling procedure to recreate an empirical sampling distribution of this estimator. The main advantage of such a procedure is that the sampling distribution is not mathematically estimated but empirically reconstructed based on all the original characteristics of the data. Thus, it automatically takes into account distribution properties that are generally considered as contaminating factors, such as skewness, ceiling effects, outliers, etc. This feature makes bootstrap estimations adequate even when data are not normally distributed.

**Experiment 2.** Twelve new volunteers, 5 males and 7 females, aged 23–48 years (mean 25.3), were recruited for a guessing task as in the previous experiment.

All participants were invited to the same laboratory used for experiment 1. The experimental procedure and the method of heart rate measurement were identical to those used in experiment 1.

### *Data Analysis*

The raw heart rate data were analyzed as in experiment 1, but, given the confirmatory nature of this second experiment, we used a one-sided probability.

### *Heart Rate*

The overall comparison between target and nontarget yielded a statistically significant difference of 0.57 (C.I. 95% ± 0.33).The paired *t*-test was $t(2399) = 3.4$, $p = 0.001$, effect size $d = 0.054$. A bootstrap analysis, conducted as in experiment 1, confirmed this result, $t(2399) = 3.38$ (C.I. 95 ± 1.98).

### *Hits*

As in the first experiment, the mean of targets correctly identified was close to the chance level, $M = 6.08$, $SD = 1.86$.

### *Comparison between the Two Experiments*

Figures 2a and 2b illustrates the comparison between results for targets and nontargets obtained in the two experiments. The results obtained in the second experiment replicate the difference between heart rates related to targets and to nontargets observed in the first experiment. Even if further replications are necessary, this result confirms that heart rate is a reflection of the intuitive cognitive activity performed in the two experiments. We are now more confident of the reliability of these differences and ready to discuss their psychophysiological relevance.

## CONCLUSIONS

With a simple procedure, it was possible to detect an anticipatory subtle heart rate change according to the target category based on the intuitive cognitive activity of subjects even if their conscious choices were random. The probability that the observed results may be a consequence of statistical artifacts, even if always present, may be considered low because of the concordant findings of the exploratory and the confirmatory experiments and our use of the bootstrap procedure in the data analysis. We are aware that the small differences observed were extracted thanks to the high number of data points necessary to obtain a satisfactory statistical power and, consequently, that their practical sig-

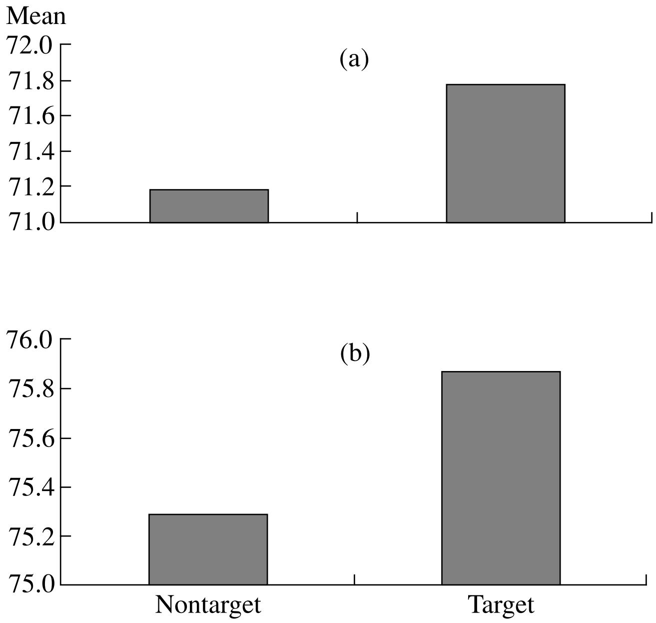


**Fig. 2.** (a) Means of heart rate associated with targets and nontargets in the first experiment; (b) means of heart rate associated with targets and nontargets in the second experiment.

nificance may be limited. However, even if the raw difference between targets and nontargets is very low, corresponding approximately to less than one beat per minute, it seems possible to detect it using a rather unsophisticated technology.

The results obtained in the two experiments seem quite reliable and sufficient to be considered an expression of a real effect supporting and extending the model of Bechara *et al.* [14, 15] of a double, partially independent information processing system underlying our intuitive cognitive problem-solving activity. The conscious, or declarative, system allows us to use our verbal and reasoning processes to arrive at a decision. At the same time, a nondeclarative, unconscious system provides a sort of covert bias using a different neurophysiological network, for which the ventromedial frontal lobes seem to be the key component [13].

Further investigations must be conducted in order to clarify how these two parallel but interacting systems influence each other and to better comprehend their adaptive value. What seems to emerge is that some psychophysiological responses, such as heart rate and skin conductance, are pieces of "unconscious cognitive" information that function as orienting signals to support "conscious cognitive" decisions. How this information may be voluntarily or involuntarily exploited for advantageous decisions remains a fascinating empirical question.

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