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Event-related markers of unconscious processes

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Abstract

A series of studies is reviewed strongly suggesting that event-related potentials (ERPs) may provide markers for unconscious processes. In one study it was shown that, although smaller in amplitude by at least a factor of four, ERPs to subliminal stimuli have a similar component structure to ERPs to supraliminal stimuli. In another study, it was shown that an oddball P300 could be obtained for subliminal stimuli. In two additional studies, it was shown that aversive conditioning could be established unconsciously. The implications for our understanding of the role of unconscious processes in phobias and post-traumatic stress disorders are discussed, as well as more general implications for memory formation. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Unconscious processing; Subliminal stimuli; ERPs; Aversive conditioning; Phobias; Post-traumatic stress disorder; Memory

1. Introduction

One of the more interesting and important recent developments in psychology and neuroscience has been the increasing number of investigations devoted to determining the existence and nature of unconscious processes. No longer is interest focused narrowly either on behavior alone or consciousness alone, but the focus has been broadened to encompass the influence of unconscious processes on behavior and consciousness. The term unconscious has generally come to refer to mental processes, such as perception and memory that appear to have some of the same properties as conscious processes, but lack awareness.

The research to be reported in this article emerged from a pioneering effort to study unconscious processes long before more general interest had emerged. In an article published in Science in 1968, Shevrin and Fritzler reported the first subliminal visual evoked-potential markers for complex non-verbal stimuli. A component approximating what is now called P200 was found to

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in improving subliminal methods. The research to be reported has benefited from these advances. Nevertheless, skepticism continues to exist concerning both the possibility of ERPs serving as markers of unconscious processes and whether unconscious processes can be measured without artifact. I will provide evidence from our laboratory for a number of propositions that should lessen skepticism on both counts. For the sake of brevity, the terms 'subliminal ERPs' and 'supraliminal ERPs' will be used in place of 'ERPs to subliminal stimuli' and 'ERPs to supraliminal stimuli'. These propositions are:

1. Subliminal ERPs have a component structure similar to conventional supraliminal ERPs.
2. Subliminal ERP components have similar psychological properties to conventional supraliminal ERPs.
3. Subliminal ERPs can be used to address a number of questions of theoretical interest regarding
   - Acquisition of unconscious aversive conditioning;
   - Effects of conscious aversive conditioning on subsequent unconscious processing; and
   - Registration and encoding of unconscious affect valence.

2. Methodology

Before addressing the propositions just presented, one central issue in subliminal methodology needs to be discussed. Over the years, controversy about the existence of unconscious processes has focussed on the need to develop a powerful method of subliminal activation that would not be subject to the criticism that the method failed to exhaustively sample consciousness. Perhaps what appeared to be subliminal effects were really accounted for by some residual consciousness. Controversy centered on the important distinction between the objective and subjective threshold (see Snodgrass, in press, for a full exposition of this controversy). According to

differentiate between two subliminally-presented stimuli (see Fig. 1). Subsequently, these findings were replicated (see Shevrin, 1973 for a review of these early studies). The inference that an ERP to a stimulus that the subject cannot report seeing is correlated with an unconscious mental process is based on the same reasoning applied in any supraliminal study in which differences in ERPs that vary systematically with differences in stimulus and/or response conditions.

In the intervening years, much greater sophistication has been achieved in measuring ERPs and
signal detection theory (SDT), at the objective detection threshold, discrimination between stimulus and no stimulus conditions is at \( d' = 0 \). At the subjective threshold, on the other hand, discrimination is above chance (\( d' > 0 \)), but the subject claims not to have seen anything. In SDT terms, at the subjective threshold, the presence or absence of conscious processing is measured by a subjective criterion rather than by a measure of actual sensitivity. Classical psychophysical methods have relied on the subjective criterion and were in fact called into question by STD advocates for precisely that reason. The argument was made early on by STD advocates that, at the subjective threshold, what purports to be unconscious is conscious, but below the subject’s criterion for consciousness. This would particularly effect stimuli that are only briefly presented. All of the research described below was conducted at the objective detection threshold and is, thus, not subject to the SDT criticism of subliminal research based on the subjective threshold (see Snodgrass, in press, for a thorough examination of these issues).

3. Subliminal ERPs have a component structure similar to conventional supraliminal ERPs

In an ERP study of unconscious affect valence (described more fully below), Bernat et al. (in press (a)) were able to demonstrate that subliminal ERPs have a component structure similar to conventional supraliminal ERPs. In Fig. 2, in which the plots are grand averages (\( N = 3264 \) per wave) for electrode P3, the upper two plots compare the supraliminal grand average (solid line) with the subliminal grand average (dashed line). The subliminal grand average looks very much like a flat line, confirming the doubts of those who are skeptical that ERPs can measure subliminal effects, even assuming that these effects exist. However, if one plots the subliminal grand average ERP with amplitude scale raised by a factor of four, the subliminal ERP reveals a structure remarkably similar to the supraliminal ERP to the same stimuli (lower two plots in Fig. 2). The similarity is further confirmed by sizeable correlations between supraliminal and subliminal ERPs registered from the same electrode sites: \( F_3 = 0.91, F_4 = 0.91, CzPz = 0.85, P_3 = 0.66, P_4 = 0.80, O_2 = 0.48 \) (for all correlations \( P < 0.001 \)) (electrode site CzPz is at one-third of the distance from Cz to Pz). The initial flat-appearing subliminal grand average ERP is revealed to be a function of scale. The brain is responding with a similar array and sequence of components, but at much lower amplitudes. It remains to be seen if the subliminal components are correlated with psychological functions similar to those found for supraliminal ERPs.

4. Subliminal ERPs have similar properties to conventional supraliminal ERPs

In order to demonstrate that subliminal ERPs have similar psychological correlates to conventional supraliminal ERPs, Bernat et al. (2001) chose what is perhaps the most frequently researched and best established ERP component finding — the odd-ball P300 effect. The words LEFT and RIGHT were presented in a counterbalanced odd-ball design subliminally and then supraliminally. Stimuli were presented in 60 blocks each containing five stimulus presentations (four frequent and one rare) in an 80/20 frequent/rare ratio. Thus, each subject was presented with 300 stimuli, 240 frequent and 60 rare. There were 28 subjects. As mentioned previously, the words were flashed subliminally at the objective detection threshold. The actual duration and luminance were 1 ms at 5 foot/Lamberts. Stimuli were delivered in a Gerbrand three-field tachistoscope. The findings confirmed that a P300 component was significantly greater for the less frequent (either LEFT or RIGHT) than for the frequent stimulus across Fz, Cz, and Pz \( (F_{1,27} = 5.75, P < 0.012) \) (Fig. 3). The results strongly suggest that the odd-ball P300 is present for subliminal stimuli. If that is, in fact, the case, as our results suggest, it means that context updating, one widely held understanding of the odd-ball effect, can occur unconsciously.

There was another finding in the study that is of theoretical and methodological interest. Al-
Subliminal vs. Supraliminal Grand Averages Show Similarity in Structure

Electrode P3; correlation=.66, p<.001; N=3264 per wave

![Graph showing sub and sup averages on the same scale.](image)

Correlation for other electrodes - F3=.91; F4=.91; CzPz=.85; P3=.66; P4=.80; Oz=.48

![Graph showing sub average multiplied by 4.](image)

Fig. 2. Comparison of supraliminal and subliminal grand average ERPs at electrode P3 based on 3264 iterations. Plots in the pair of upper curves are on the same amplitude scale. In the lower plots, the subliminal ERP has been multiplied by a factor of four at each time point, revealing substantial structural similarity with the supraliminal ERP as reflected in substantial correlations (Bernat et al., in press (a)).

though it was the case that, on average, in a test of detectability actual detection was at the objective threshold (\(d' = 0\)), as expected in any distribution of scores, a number of subjects were above \(d' = 0\). It could be argued that these subjects were, in fact, detecting something and that it was these subjects who accounted for the subliminal odd-ball effect. If this were the case, one would expect a positive correlation between those scores above \(d' = 0\) and the odd-ball effect. The correlation was computed between the \(d'\) score and the average across the three electrodes and for each electrode separately for the experimental effect, defined as the difference in amplitude between the P300 for the rare and frequent stimuli. The P300 was defined as occurring in the 400–760-ms window, as determined by a principal component analysis. For the average across electrodes, the correlation was significantly negative (\(R = -0.44\), d.f. = 25, \(P < 0.011\), one-tailed test). For the three electrodes separately the correlations were individually significant and negative (Fz: \(R = -0.48\), d.f. = 25, \(P < 0.006\), one tailed test; Cz: \(R = -0.34\), d.f. = 25, \(P < 0.043\), one
Fig. 3. Comparison of ERPs to subliminal infrequent (odd-ball) stimuli with ERPs to frequent stimuli at electrodes Fz, Cz, Pz and EOG filtered at 7 Hz (Bernat et al., in press (a)).

tailed test; Pz: \( R = -0.37, \) d.f. = 25, \( P < 0.028, \) one tailed test). Rather than helping, any detectable consciousness of the stimulus inhibited the subliminal effect. From a methodological standpoint, this finding provides substantial support for the conclusion that the odd-ball effect obtained in this study was unconscious. From a theoretical standpoint, the finding points to the way in which conscious processes interact with and, under certain conditions, can inhibit unconscious processes. We have found similar relation-

ships in other cognitive studies (Snodgrass et al., 1993; Snodgrass, in press).

5. Subliminal ERPs can be used to address a number of questions of theoretical interest

5.1. Can subliminal ERPs be used to index the acquisition of unconscious aversive conditioning?

For some time it has been maintained in the literature that for aversive conditioning to occur, there must be conscious awareness of the relationship between the conditioned and unconditioned stimulus (Dawson et al., 1987). Awareness of the conditioning relationship is necessary for any of the conditioning effects on memory or behavior to occur. This is felt to be particularly true for trace conditioning, in which there is a time interval between the end of the conditioned stimulus and the onset of the unconditioned stimulus so that a memory of the conditioned stimulus must form and be related to the subsequent onset of the unconditioned stimulus. Clarke and Squire (1998) and Schacter (1998) have taken this position a step further and have argued that these requirements for trace conditioning fit with their understanding of the formation of declarative, conscious memories that depend on an intact hippocampus. Our subliminal methodology permitted us to test this hypothesis. If consciousness was essential for aversive trace conditioning to occur, then subjects should fail to give evidence of conditioning when the stimuli were presented subliminally.

In two studies, the second a conceptual replication and extension of the first, we found that aversive conditioning could be established unconsciously (Wong et al., 1997; Bernat and Shevrin, 2000). In the first study, two schematic faces, one with a happy and the other with an unhappy expression, were presented at 1 ms at 5 foot/Lamberts. The unhappy face (CS+) was conditioned to a mild electric shock presented 800 ms later, the happy face (CS−) was not. Prior to the subliminal conditioning phase, a baseline supraliminal condition was administered.
in which the faces were consciously perceived. Following the subliminal conditioning phase, the faces were again presented supraliminally.

The main finding was a significant interaction between electrode, pre- and post-conditioning and the CS+ vs. the CS− for P3b (\(F_{3,24} = 4.56, P < 0.011\)). At Pz the CS− decreased significantly from pre- to post-conditioning (\(F_{1,8} = 7.82, P < 0.02\)), while the CS+ showed no comparable habituation.

Although the findings were positive, the absence of a factorial design, in which both stimuli were conditioned alternately, weakened the conclusiveness of the study. A second study was designed to repair this weakness (Bernat and Shevrin, 2000). In addition, the stimuli in the second study were words in order to determine if purely verbal stimuli could be aversively conditioned subliminally. The words were both extremely negative — murder and cancer — so that the only difference would be whether the word had been conditioned. The unconditioned stimulus was a segment of white noise. In all other respects the design was similar to the first. The original P3b finding was replicated: \(F_{1,25} = 4.978, P < 0.035\).

The findings from both studies support the view that aversive conditioning can occur unconsciously. Unlike the position taken by Dawson et al. (1987), and the hypothesis concerning declarative conscious memories offered by Clarke and Squire (1998) and Schacter (1998), the perception of a relationship between the conditioned and the unconditioned stimulus need not be conscious for conditioning to occur, nor is consciousness necessary for declarative memories to form.

5.2. Can ERPs be used to detect the effects of conscious aversive conditioning on subsequent unconscious processes?

In an earlier companion study to the first unconscious conditioning study (done with schematic faces), conditioning was conducted in consciousness and the effects tracked in a subsequent subliminal phase (Wong et al., 1994). Also part of the design was a pre-conditioning subliminal baseline phase. The finding of interest was the appearance in the subliminal post-conditioning phase of a significantly greater negative voltage component to the previously conditioned unhappy face than to the unconditioned face, approximately 500 ms prior to when the unconditioned stimulus had appeared in the conditioning phase. This effect was found at Cz: \(F_{1,16} = 4.52, P = 0.05\). Both the negativity and location of the response prior to the time of occurrence of the aversive stimulus strongly suggests that an expectancy wave or tCNV is involved (Klorman and Ryan, 1980). If so, then it would appear that, even though the subject was entirely unaware of which face had been presented, the ERP revealed that only following the conditioned stimulus did the subjects expect a second stimulus at approximately the same time as when the mild shock had been delivered during the conditioning phase. What had been consciously learned as an aversive stimulus could operate unconsciously to produce a learned expectation of that aversive stimulus of which the subject was unaware.

5.3. Can ERPs index unconscious affect?

In a study designed to investigate if the processing of positive and negative affect valence can occur unconsciously, Bernat et al. (in press) presented 10 highly negative and 10 highly positive affect words to 17 subjects both supraliminally and subliminally. ERP components P1, N1, P2, P3, and a late positivity, LP, were measured at six electrode sites F3, F4, P3, P4, CzPz and Oz. The stimuli were each presented 32 times for a total of 1280 presentations in randomized order by an experimenter blind to their content. The subliminal condition (1 ms) preceded the supraliminal condition (40 ms). The subliminal conditions again met the objective detection standard (1 ms at 5 foot/Lamberts), and detection did not differ from the chance mean of 15 [mean = 14.35, \(t(16) = 0.94, \text{ns}\)].

A main finding for the supraliminal condition, supporting previous findings reported by Cacioppo et al. (1996), was that negative as compared to positive affect valence was associated with greater ERP positivity, most clearly for P300 (\(F_{1,17} = 11.38, P < 0.004\)) and for a late positive component (\(F_{1,17} = 4.70, P < 0.046\)) (see Fig. 4).
Fig. 4. Supraliminal ERP comparisons for pleasant and unpleasant words at F3, F4, CzPz, P3, P4 and Oz (Bernat et al., in press (a)).
Interestingly, for the subliminal condition, an interaction between hemisphere and affect valence was found ($F_{1,17} = 6.53, P < 0.021$) (see Fig. 5).

For each component greater positivity for the negative affect words was found for the left hemisphere (P1: $F_{1,17} = 6.63, P < 0.020$; N1: $F_{1,17} = $

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Fig. 5. Subliminal ERP comparisons for pleasant and unpleasant words at F3, F4, CzPz, P3, P4 and Oz (Bernat et al., in press (a)).
5.47, P < 0.033; P2: \( F_{1,17} = 4.93, P < 0.041; \) P3: \( F_{1,17} = 8.78, P < 0.009; \) LP: \( F_{1,17} = 14.89, P < 0.001)\).

These unexpected lateralization findings for the subliminal ERPs call attention to possible qualitative differences between conscious and unconscious affective processing. Supraliminally, there was evidence that, for the earlier components (P1 and N1), left lateralization was also present (P1: \( F_{1,17} = 11.40, P < 0.004; \) N1: \( F_{1,17} = 8.29, P < 0.011)\), but the effects became bilateral for P300 and LP. This difference cannot easily be explained by the left lateral processing of words, because the same words were used for the supraliminal presentations and they resulted in bilateral findings for P300 and the LP. Nor does this finding fit with the thesis advanced by Galin (1974) and Schore (1997) that the right hemisphere is the locus of unconscious processing. More research will be needed to arrive at a clearer explanation of this left lateralized finding for subliminal affect processing.

It is also of interest that P200 was found to differentiate affect valence subliminally but not supraliminally. In the earliest study reported on subliminal visual ERPs, it was a component at approximately P200 that differentiated the experimental from control stimulus (see Fig. 1).

6. Implications

What are the implications of the reported research? First, from a methodological standpoint, the research provides strong evidence for the assertion that unconscious processes are instantiated in electrophysiological events. Although appreciably smaller in amplitude, subliminal ERPs appear to have the same component structure as supraliminal ERPs and may serve as markers for unconscious processes.

Secondly, as the subliminal odd-ball study demonstrates, these subliminal components are correlated with psychological processes that are quite similar to those occurring supraliminally. The subliminal odd-ball finding suggests that at least some of our understanding of the supraliminal odd-ball effect may also apply to unconscious odd-ball effects.

Taken together, these two sets of findings strongly suggest that ERPs are a valuable tool for investigating unconscious processes.

In the two subliminal aversive conditioning studies, we saw how subliminal ERPs can help answer an important theoretical question: can aversive conditioning occur unconsciously? The cited results suggest that the answer is yes. An affirmative answer has many implications. There are two of special interest:

1. Since it has been held that trace conditioning (the type used in these studies) requires an intact hippocampus essential to forming declarative memories that can only occur consciously (Clarke and Squire, 1998; Schacter, 1998), our finding raises the possibility that declarative memory can form unconsciously and that an intact hippocampus may be a necessary condition for declarative memory formation but it is not a sufficient condition for consciousness. Indeed, Schacter (1998) has advanced the hypothesis that the capacity to form trace conditioning might serve as an index of consciousness in animals.

2. If aversive conditioning can occur entirely unconsciously, then it is possible to imagine that many phobias may have an unconscious origin. It is also likely that post-traumatic stress disorder (PTSD) sufferers form many unconscious links between various stimuli encountered during the precipitating trauma. Treatment of phobias and PTSD patients may need to take into account the real possibility that conscious efforts at retrieval of significant precipitating events may not be possible, and other means will need to be found.

In the supraliminal conditioning study, we found that expectations can be at work unconsciously. This finding opens the door to the possibility that conscious learning results in expectations that operate entirely unconsciously. Environmental cues may be slight and even subliminal, but would still be sufficient to activate an
unconscious expectation of an untoward event, such as the approach of a predator, or of any learned danger. One can see the adaptive advantage of this kind of mechanism. Also important is the implication that the activation of an unconscious expectation of a danger may be only one of a greater class of unconscious expectations that play a role in everyday behavior, both normal and pathological.

The existence of unconscious affect is of special importance because affect has been considered by many theorists, as well as in common sense experience, to be the quintessential conscious experience. While there has been growing acceptance of unconscious perception and unconscious memory, the possibility of unconscious affect has not met with the same readiness of belief. Certainly, the unconscious aversive conditioning studies lend support to the proposition that affects can be formed unconsciously and have conscious effects.

Taken together, the findings support the hypothesis that unconscious processes play an important role in mental life, and that ERPs can be used as markers for these unconscious processes.

References


