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Chapter VIII

THE EMOTIONAL S1-S2 PARADIGM FOR EXPLORING BRAIN MECHANISMS UNDERLYING AFFECTIVE MODULATION OF EXPECTANCY

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ABSTRACT

From the past decade to date, research on the interactive brain mechanisms between attention and emotion studied through event-related potentials (ERPs) has increasingly grown. This brain signal reflects fast and swift cognitive processing due to its excellent temporal resolution and it has become a suitable tool in order to study several issues concerning cognitive processing. In this chapter we present a detailed description of an 'emotional variant' of the S1 (cue)-S2 (target) task that has been typically used to explore vigilance-related attention. The application of the emotional S1-S2 paradigm elicits an affective modulation effect on a brainwave that has been related to expectancy, the early Contingent Negative Variation (eCNV). In this chapter we will present several issues concerning different methodological aspects to take into account when applying this paradigm and some details related to the procedures of quantification and analysis of the ERP data. Finally, some findings obtained through the use of the emotional S1-S2 protocol are summarized and some of its different application possibilities (e.g., clinical samples) are proposed.

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INTRODUCTION

Selective attention constitutes a necessary cognitive process to effectively cope with our dynamic and changing world. Through this mechanism, relevant aspects such as affective information are prioritized in awareness not only to improve stimulus perception but also to prepare people for its forthcoming processing. The S1-S2 paradigm has shown to be a useful tool in order to cast light on the selective attentional aspects related to vigilance or expectancy processes towards next upcoming events. In its conventional form, this paradigm comprises of the presentation of a signal stimulus (S1) that indicates the target (S2) appearance in each trial (Walter et al., 1964; McCallum, 1988). Usually, the subject is instructed to respond to S2 as fast as possible.

Because attention involves short and fast subprocesses, some of them occurring during the first 500 milliseconds after the stimulus onset (Mangun and Hylliard, 1995), the use of event-related potentials (ERPs) methodology constitutes a helpful strategy that allows us, due to its privileged temporal resolution, to obtain data of the successive stages of these attentional subprocesses. The main ERP wave evoked by applying the S1-S2 protocol is the Contingent Negative Variation (CNV) (e.g., McCallum, 1988; Weinberg, 1972). This negative component that appears just after S1 (cue stimuli) reaching its end before S2 offset, is comprised of two adjacent but dissociable waves, the 'early' CNV (eCNV) and the 'late' CNV (lCNV). Whereas the lCNV seems to reflect preparation for motor activity (e.g., Van Voxtel and Brunia, 1994), the eCNV is directly linked to vigilance-related attention to forthcoming stimuli (Rohrbaugh and Gaillard, 1983; Basile et al., 1994). Vigilance-related attention refers to a general alert state that is necessary when a situation requires a sustained level of attention, such as that related to prioritize the processing of forthcoming relevant information (Posner and Petersen, 1990).

Neurocognitive scientists have developed several modifications of the S1-S2 experimental protocol to study particular cognitive processes. Thus, it has shown to be useful to study long-term memory encoding (Leynes et al., 1998), visuospatial orienting attention (Talsma et al., 2005), temporal attention (Miniussi et al., 1999; Correa et al., 2006) or developmental differences in the saccadic CNV (Klein et al., 2005), among other processes. However, the use of the S1-S2 paradigm for studying the interaction between vigilance-related attention and emotion is rather scarce in relation to brain activity, even though from past decade there has been an increased interest to explore these issues. This lack of data is surprising since the need to be prepared for situations that involve the processing of upcoming affective events are frequent in every day's life. Some ERP studies have shown that the eCNV is sensitive to cues signalling the appearance of emotional targets (Yee and Miller, 1987; Regan and Howard, 1995) as well as socially relevant information, such as faces (Mantsakanian and Tarkka, 2002). Also, CNV amplitude has been related to expectancy when high-anxious subjects performed a S1-S2 stressful task (McCallum and Walter, 1968; Proulx et al., 1984). Recent data have shown larger lCNV amplitudes related to the expectancy of aversive consequences following S1 stimulus in panic disorder patients (Amrhein et al., 2005). Despite the interesting data provided by these experiments, however, most of these studies did not differentiate between early and late CNV subcomponents. Moreover, these studies did not manipulate the emotional meaning conveyed by S1 and S2.

In order to overcome these limitations, we propose in this chapter the emotional S1-S2 task, an experimental paradigm that consists of an 'emotional variant' of the S1-S2 task and an analytical procedure that allows for the differentiation of the early and late subcomponents of the CNV. As we will explain later in detail, in this paradigm, target stimuli are explicitly emotional while cue stimuli (which are neutral) signal in an implicit way the emotional category of the following target. Participants are asked to detect cue-target correspondences. The affective value of targets is manipulated according to two dimensions: valence (positive-negative) and arousal (arousing-relaxing) (for additional information see Russell, 1979; Lang et al., 1997). The combination of these two dimensions may yield to four emotional categories: arousing-positive, arousing-negative, neutral and relaxing stimuli. Some other combinations of the valence and arousal dimensions, such as relaxing-negative stimuli are virtually impossible (Lang et al., 1997).

The steps for the implementation of this paradigm in ERP research will be described in detail in the following section. Also, possible variants of some aspects of the emotional S1-S2 paradigm will be outlined.

DESCRIPTION AND APPLICATION OF THE EMOTIONAL S1-S2 PARADIGM

As indicated in the introduction section, the experimental design that will be described here is an emotional variant of the S1-S2 paradigm. This emotional S1-S2 paradigm comprises the sequential presentation of two stimuli, the S1 or *cue* stimulus and the S2 or *target* stimulus. This emotional S1-S2 task has two specific features. First, the target or S2 stimulus has emotional (or emotionally neutral) content. Second, the cue or S1 stimulus should be devoid of emotional content emotional but created in a way that lead the participants to conceive implicit expectancies concerning the emotional content of the forthcoming target stimulus. The reason for S1 stimuli to be non-emotional is that neural activity between S1 and S2 should reflect expectancy related differences, but not emotional reactions to S1. Although auditory stimuli (tones) have been used as cue stimuli (Carretié et al., 2004a), most of the studies employing this paradigm have used visual stimuli as both cue and target stimuli (e.g. Carretié et al. 2001; Amrheim et al., 2005). Whatever the case, it is important to equate the physical features of the stimuli (such as contrast, complexity or brightness in the case of the visual modality) so they differ only in their emotional content.

Target stimuli belong to different emotional categories that differ in valence, arousal, or both dimensions: negative stimuli (A-, negative valence and high levels of arousal), positive stimuli (A+, positive valence and high levels of arousal), relaxing stimuli (R, positive valence and low levels of arousal) and neutral stimuli (N, neutral in both valence and arousal). As mentioned before, cue stimuli are stimuli devoid of emotional content that have to be associated with target stimuli. It is important to notice that each cue stimulus has to be matched to a particular category of target stimuli. Several types of stimuli can be used as cues, such as schematic drawings, geometric figures or even tones. Each trial begins with the presentation of the cue followed by the presentation of the target after a variable time interval, both centred in the screen. A brief beep could be presented 1500 or 2000 milliseconds after the target that allows participants to provide a motor response that does not interfere with the recording of cognitive processing responses. For instance, eye-blinking and other eye movements usually constitute an important artefact when the experimenter carries out the correction and analysis of the ERP data (Picton et al., 2000). Although the use of algorithms for the correction of eye movements is a frequent practice in signal analysis, when EOG activity is intense the efficacy of these methods decreases. Since participants can not remain without blinking for long periods of time, it could be also helpful to tell them to blink at the same time they provide with a response (after the beep presentation, for instance). It should be noticed that this paradigm also allows investigating attentional processes related to input-processing (i.e., those appearing after post-target stimulation). Motor electrophysiological artefacts produced by the participants' responses during the experimental task could distort the amplitude and latency of some attentional ERP components (e.g., Picton et al., 1995). In this sense, the experimental design is free of this caveat since participants are asked to postpone their motor responses until the beep presentation. However, this way of proceeding has some limitations. In this regard, this task configuration does not allow collecting behavioural data about reaction times linked to target presentation.

The duration of the stimuli, the time interval between the presentation of the cue and the target stimulus and the inter-trial interval varies across studies. Thus, the duration of the cue and target stimuli usually ranges between 200 and 500 ms and the inter-trial interval usually ranges between 2500 and 4000 ms (e.g., Armheim et al., 2005; Mantsakanian and Tarkka, 2002). More relevant is the interval between the cue and the target stimulus, that usually ranges between 1500 and 4000 ms (Rockstroh et al., 1989; Rosahl and Knight, 1995). The temporal point at which target is cued to appear could modulate brain expectancy-related responses. Different time intervals between cue and target stimuli (short: around 500 or 600 ms; long: around 1500 ms) might be used to override this issue (Correa et al., 2006). Moreover, some studies have shown that several brain areas involved in cognitive expectations are differently activated as a consequence of this manipulation (e.g. Coull et al., 2000). Results of some studies suggest that, although the CNV is typically observed at long and fixed cue-target time intervals, a negative deflection with temporal and topographic characteristics resembling those of the eCNV could be attenuated or even eliminated at short cue-target time intervals, whereas its amplitude increases at long cue-target intervals (Talsma et al., 2005). Indeed, as some authors have pointed out, the time interval between the presentation of the cue and the target stimuli could influence the reliable dissociation on the two subcomponents of the CNV (Kropp et al., 2000; Brunia and van Boxtel, 2001). Figure 1 provides with a schematic description of the paradigm.

With respect to the experimental task, participants should be informed that they are going to see or hear a stimuli (S1) followed by a second stimuli (S2). The correspondence between each cue and each particular target stimulus has to be explicitly explained to participants and trained. In this sense subjects should have the opportunity to perceive all cue types and to associate them with each target type before the recording session.

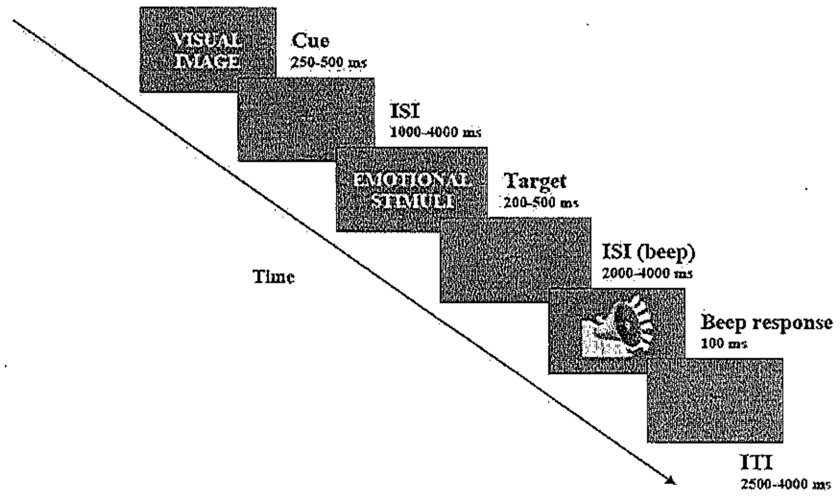

Figure 1. Schematic representation of the emotional variant of the S1-S2 paradigm described in the main text. ITI= Inter-trial interval; ISI= Inter-stimulus interval.

It is important to use an indirect task that keeps hidden the explicit objective of experiment (i.e., that it deals with emotional processing), since non-indirect procedures may lead participants to consider that some stimuli are more important than others (i.e., emotional, salient stimuli, more important than non-emotional ones for an experiment that deals with emotional reactions). This 'relevance-for-task effect' has often been described in previous research (e.g., Duncan Jonhson and Donchin, 1977). It showed that stimuli considered by subjects to be highly relevant for the task elicit higher amplitudes in certain endogenous components compared to less relevant stimuli. Indeed, the ERPs elicited by emotional stimuli in direct tasks are different from those elicited in indirect tasks (e.g., Carretié et al., 1997). Therefore, presenting the participants with a matching cue-target task ensures to distract their attention from the emotional meaning of stimuli so the allocation of the same amount of attentional resources towards every stimulus is guaranteed.

A good example of such a type of task is provided in Carretié et al. (2001). In this study the cue stimuli consisted of a pair of schematic drawings (one above the other) that implicitly provided information about the emotional content of target stimuli (pictures). Both drawings in the cue stimuli signalled targets belonging to the same emotional category (for instance a cue stimulus represented the schematic drawing of a wolf jaw and an insect, corresponding to targets of the negative category). Examples of stimuli are provided in Figure 2. Target pictures corresponded always to one of the two schematic drawings of the cue stimuli. Participants had to press a button whenever the target corresponded to the drawing that appeared in the top of the cue stimuli or a different button when the target corresponded to the bottom drawing.

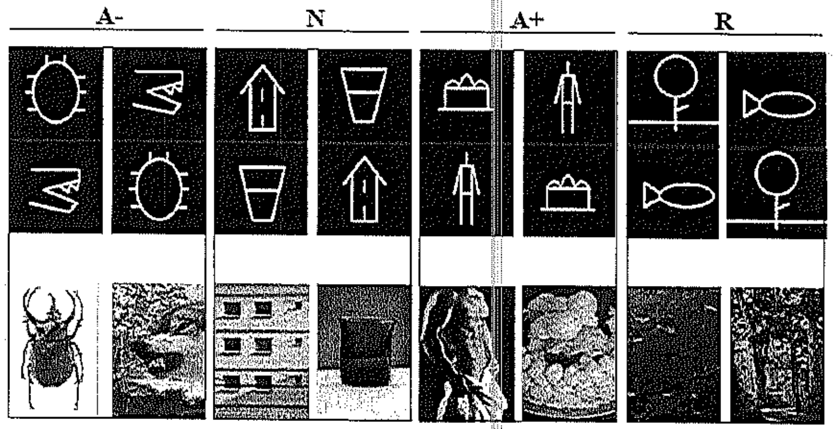

Figure 2. Examples of cue and target stimuli used in the task by Carretié et al. (2001). In the top of the Figure, starting from the left to the right schematic drawings of negative (A-), neutral (N), positive (A+) and relaxing (R) stimuli. In the bottom the pictures of the corresponding target stimuli are shown.

Another relevant aspect has to do with the choice of emotional stimulation which constitutes also a critical issue. A non-rigorous method for controlling stimuli might cause unexpected and unreliable results. For example, positive and negative stimuli should differ in valence but not in arousal. This would prevent from reaching an unequivocal conclusion about which of the two dimensions is explaining the results. In order to avoid these concerns, a careful selection of the emotional stimuli should be made. In this sense, the use of a validated database of emotional images, such as the IAPS (Lang, 2001) could be useful. However, this method is not free of some caveats. One has to do with the application of a standardized database on people of different cultural status (e.g., Latin and Anglo-Saxon populations), since these cultural differences could influence the emotional processing of the stimuli. Therefore, it is of the greatest importance to collect the particular assessment of the participants for every emotional target stimuli used in the study in order to confirm that the valence and arousal of the stimuli are those supposed a priori to be (e.g., Carretié et al., 1997). For this purpose a bidimensional scaling test (for instance with a five-point scale) can be supplied to participants after the recording session.

ISSUES RELATED TO ELECTROPHYSIOLOGICAL DATA ANALYSIS

Concerning the statistical analysis of the ERP data, the use of some procedures might lead to a more reliable interpretation of the results. The waveform recorded at a site on the head over a period of several hundreds of milliseconds represents a complex superposition of different overlapping components. Although the visual inspection of grand-averaged ERPs has been the method more frequently used to detect components, its exclusive use should be taken with caution since this method may lead to several types of misinterpretation especially

when high-density montages are employed (e.g, Chapman and McCrary, 1995; Dien et al., 2005; Donchin and Heffley, 1978). In order to override these shortcomings, temporal principal component analysis (tPCA) has been repeatedly recommended as the most reliable reduction, detection and quantification method for multivariate ERP data (e.g., Dien et al., 1998). Its main advantage is that it represents each ERP component with its 'clean' shape by extracting and quantifying them free of the influences of adjacent of subjacent components. Indeed, the application of tPCA avoids the subjectivity of selecting time windows for component analyses. In brief, the tPCA computes the covariance between all ERP time points, which tends to be high between those time points involved in the same component, and low between those belonging to different components. The solution is therefore a set of independent factors made up of highly covarying time points, which ideally correspond to ERP components. Temporal factor scores, the tPCA-derived parameter in which extracted temporal factors may be quantified, are equivalent to amplitude.

In the attention-research field, the usefulness of the PCA for disentangling spatiotemporally overlapping ERP components has been demonstrated recently in several studies (Beauducel et al., 2000; Debener et al., 2005; Dien et al., 2003). In this sense, despite of the fact that some studies have found that inter-stimulus intervals as long as 2-3 seconds are a necessary condition for a reliable dissociation of the two components of the CNV (Kropp et al., 2000), the use of the PCA allows for separation of the eCNV and the lCNV even with time-intervals shorter than 2 seconds (Carretié et al., 2001).

It is important to keep in mind some recommendations when the PCA is employed to analyze ERPs. For instance, the use of a covariance matrix has been strongly recommended with respect to correlation matrix-based analysis (Kaiser and Tenke, 2003; Dien et al., 2005). Also, the scree test is considered an optimal procedure to determine the number of factors that are retained or selected (Dien, 1998). Special caution should be taken in relation to the rotation method chosen since there is still not a total agreement. In this regard, whereas Kaiser and Tenke claim for the use of orthogonal rotations such as Varimax, Dien and co-workers have shown the advantages of oblique rotations such as Promax since this method considers brain components or factors as entities that are physiologically associated (see Dien et al., 2005; Kaiser et al., 2003, for a detailed discussion of caveats concerning the PCA analyses on ERP data). Our own experience also supports the advisability of oblique procedures such as Promax.

Additionally, the potential superposition of different ERP components can also complicate efforts when trying to apply source localization algorithms. Thus, PCA could be a suitable tool in order to increase the reliability for determining cortical sources (Richards, 2004). In particular, the introduction of factor scores instead of voltages in source localization procedures might be helpful in those ERP components altered or hidden in grand averages but detected by PCA. In fact, the results of a recent study strongly suggest that applying a source localization algorithm (LORETA, Pascual-Marqui et al., 1994) on factor scores is a more precise procedure than the application of this algorithm on voltage amplitude values (the traditional way) (see Carretié et al., 2004b for additional information).

DISCUSSION

As a consequence of the application of this emotional S1-S2 paradigm, several ERP experiments have provided with interesting data about the spatial and temporal characterization of the attentional processing linked to emotional events. Relatively recent experiments indicated that the eCNV elicited in this task seems to be reflecting interactive mechanisms between emotional and attentional processes, since its amplitude is modulated by the affective value conveyed by forthcoming stimulation (reduced eCNV amplitudes to negatively cued events; see Carretié et al., 2001). Furthermore, this processing could be enhanced in high anxious individuals because their vigilance-related attention resources tend to be captured by stimuli that represent threat (Carretié et al., 2004a). In a further study, Amrheim and coworkers (2005) have showed that the lCNV could also be reflecting a biased processing in panic patients while they are expecting aversive consequences following the disorder-relevant stimuli.

Also, the neural generators of the 'emotional expectancy' elicited by this paradigm have been analyzed. Evidence for neural sources of the eCNV seems to point to the anterior cingulate cortex (ACC) as the brain region generating it (Carretié et al., 2001). This brain area has been proposed to be implicated in anticipatory processes of affective events (e.g., Ploghaus et al., 1999). Regarding the lCNV, some findings suggest that the dorsolateral prefrontal cortex (DLPFC) might be critical for its generation. This structure has been suggested to be involved in motor preparatory processes (Rosahl and Knight, 1995). Taking together, ERP data obtained from the application of the emotional S1-S2 paradigm show that it seems to be a promising scientific methodology for studying some aspects of the influence of emotional stimulation on the attentional brain response. The spatiotemporal characterization of these processes might be helpful in order to develop current models of the psychobiological mechanisms involved in the interaction between emotion and attention (e.g., Bar, 2003; Vuilleumier, 2002; Vuilleumier, 2005).

Finally, a few words should be devoted to the use of different types of stimuli when applying this paradigm. Although affective pictorial stimulation has largely demonstrated to be an appropriate tool when trying to elicit intense attentional reactions to emotional stimuli as compared to other types of stimulus (Bradley et al., 1998), the use of such other types of emotional stimuli should not be disregarded. The results from recent experiments show that words (see Kissler et al., 2006 for a review) or even odours (Anderson et al., 2003) are able to evoke significant emotional responses. It would be thus interesting to complement and extend the results obtained with the application of this paradigm by using stimuli belonging to different sensorial modalities.

FINAL REMARKS

Although the emotional S1-S2 paradigm has probed to bee a valuable tool in order to address issues concerning the interaction between attention and emotion processes, it also suffers from some limitations. The most important one has to do with the involvement of cognitive processes apart from attention and emotion. In order to accomplished the task requirements it is necessary to take into account processes related to working memory (see Olton et al., 1979; Kartik and Amishi, 2007). Moreover, some authors have suggested that selective attention is closely linked to working memory processes (Awh et al., 2006). This situation may lead to some confusion when interpreting the contribution of the different cognitive processes involved in the task. This limitation might be mitigated by a careful experimental design.

Despite of its potential application possibilities for exploring emotional- attention interactions, the cue-target paradigm has been scarcely used to date and further research is needed in order to investigate in more detail the issues discussed here. The paradigm has been usually tested in healthy populations, although many aspects remain still unexplored. For instance, the application of the emotional S1-S2 paradigm could extend previous findings about the emotional habituation response (Carretié et al., 2003) or the attentional regulation in elder people (Bennet et al., 2004). Also, the fact that some clinical populations show an enhanced hipervigilance towards the threatening value of different events (e.g., fear or pain-related stimuli) such as fibromyalgic (e.g., Montoya et al., 2006), or anxious patients (Mogg and Bradley, 1998), makes this protocol a promising tool in order to explore the time course of expectancy-related attentional responses to emotional stimuli in these patients. Additionally, an emotional-spatial variant can be also used to study attentional deficits in hemineglect patients (Vuilleumier and Schwartz, 2001). Finally, it would be interesting to explore the paradigm through its implementation in alternative techniques with high temporal resolution, such as the magnetoencephalography (Onoda et al., 2006).

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