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INTERNATIONAL JOURNAL OF PSYCHOPHYSIOLOGY

International Journal of Psychophysiology 54 (2004) 221-230

www.elsevier.com/locate/ijpsycho

The effects of covert attention and stimulus complexity on the P3 response during an auditory continuous performance task

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Received 13 August 2002; received in revised form 20 April 2004; accepted 29 April 2004

Available online 22 July 2004

Abstract

This study examined the effects of motor responding and stimulus complexity on the event-related potential (ERP) P3 amplitude and latency during an auditory continuous performance task (A-CPT). Subjects were presented with undegraded and degraded syllables during two experimental conditions. In the motor attention (MA) condition participants performed a button press to target syllables. In the covert attention (CA) condition, participants listened for target syllables without responding. The ERP P3 amplitude for targets during MA and CA showed the expected anterior-to-posterior scalp topography, with the greatest amplitude at Pz. Although amplitudes across all scalp sites were greater for MA than CA target P3 responses, both MA and CA targets had greater P3 amplitudes than the P3 for the nontarget syllables (NT). There was no effect of stimulus complexity (degraded vs. undegraded) on P3 amplitude. However, stimulus complexity did affect P3 latency. Degraded syllables elicited longer P3 latency than undegraded syllables for both the MA and CA conditions. The amplitude and topography findings show that when stimulus probability is controlled through the use of a CPT paradigm, a reliable P3 component is present even when the task does not require a motor response to target stimuli. © 2004 Elsevier B.V. All rights reserved.

Keywords: Attention networks; ERP; Target detection; CPT

Posner and Petersen (1990) proposed that attention involves brain networks that include the thalamus, pulvinar, superior colliculus, basal ganglia, posterior parietal regions, anterior cingulate cortex and prefron-

study by Pugh et al. (1996), using a discrimination paradigm, provided support for the neural substrates of Posner and Petersen's attention networks. The anterior network was found to be sensitive to decision and response, whereas the posterior network was most sensitive to perceptual evaluation.

tal regions. A functional magnetic resonance imaging

In a recent positron emission tomography (PET) study by our group (Benedict et al., 1998) using a relatively difficult auditory continuous performance

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task (CPT) consisting of syllables, we elaborated on the role of the anterior cingulate cortex (ACC) in auditory attention. The task required participants to detect target syllables embedded in a stream of nontarget syllables and to make a motor response to indicate that target syllables were detected. Right caudal ACC activity was observed while the participants performed this fairly complex target detection task.

Both the Pugh et al. (1996) and Benedict et al. (1998) studies required a motor response to indicate target detection. In both of these studies, activation related to attention is difficult to isolate from activation related to attention and motor responding. A previous event-related potential (ERP) study (Starr et al., 1997) addressed the issue of motor involvement in attention tasks by requiring participants to count rather than press a button to the target stimuli. The focus of this study was to investigate, using an auditory oddball paradigm, the possible effects of mental counting vs. motor responding to targets on the ERP components (including P3) of the nontarget stimuli preceding and following targets. The results showed that ERP components to nontargets in a target detection oddball task changed as a function of where the nontarget was in the stimulus sequence, and the type of response made to the target stimuli (i.e., motor or counting).

The authors suggested "that expectancy for motor response is a major factor modulating many of the evoked potential [ERP] components including..., the N100, and the amplitude of the P300."

Interestingly, since there was less than a microvolt difference for P300 to the target between the press and count conditions in the Starr et al. (1997) study, the mental count condition may not have excluded the possibility of motor involvement, such as subvocalization. In addition, counting targets likely relies on neural networks that underlie processes such as calculation and working memory and thus activation of these networks may not allow the effects of only conscious attention to be seen (Benedict et al., 1998). It is also important to note that this study used an oddball paradigm which consisted of frequent (standard) and rare (target) stimuli. The amplitude similarities between the motor and counting conditions could also be due to the nature of the oddball paradigm, in which the probability of the rare stimulus

alone can account for higher P3 amplitude than that seen for the frequent stimulus. These investigators (Starr et al., 1997) also note that although the literature indicates that ERP components [to nontargets] can change "as a function of stimulus sequence during mental counting of targets... the direction of change is not consistent among laboratories."

More recently, our group (Benedict et al., 2002) used a unique paradigm in conjunction with PET in an attempt to separate the effects of motor responding from conscious attention. Here, one of the conditions required participants to note mentally the targets without requiring an oral or manual response (covert attention, CA). As in our previous study (Benedict et al., 1998), the attention task consisted of a CPT composed of different syllables presented in a stream while participants underwent PET. Subjects had to discriminate among the different stimuli in order to identify the targets, making this paradigm different than the oddball. ERPs were obtained simultaneously to the syllables in order to determine whether the participants detected the targets and whether differences were present between the attention tasks and a passive listening control state. The ERP measures were also used to verify that participants attended to the stimuli during the CA condition and that they selectively attended to the targets compared to the nontargets. We concluded that a rostral-dorsal subdivision of the right ACC cortex is related to conscious attention for auditory stimuli when no motor response was required (Benedict et al., 2002). A greater P3 amplitude to targets relative to nontargets during the CA condition verified that the participants were attending to the target stimuli. Also, the expected P3 scalp topographical relationship associated with stimulus evaluation and target detection was present. The PET findings supported the conceptualization that the rostral division of the lateral prefrontal cortex is involved in attention and that the caudal zone of the ACC plays a role in attention requiring a motor response.

As a continuation of the PET study, we conducted another study to investigate further motor vs. nonmotor (covert) responding and the relationship between P3 and the auditory CPT used in our previous PET study. Because of the limited sample size in the PET study, broader questions about the electrophysiology and particularly about P3 and attention could not be addressed. Thus, the present electrophysiological study was conducted using the same CPT paradigm as that used in the PET study with a larger sample size.

The current literature supports the notion that the amplitude of P3 is a measure of resource allocation and attentional capacity, which is sensitive to stimulus characteristics, stimulus probability, and task relevance (Johnson, 1986; Kok, 2001). Solbakk et al. (1999) have argued, however, that the individual contributions of task evaluation, stimulus classification, and response execution are difficult to delineate with the P3 response. Other investigators (e.g., Holdstock and Rugg, 1995; Starr et al., 1997; Kok, 2001) have also questioned the relationship between P3 amplitude and latency and motor responding.

In addition to motor responding, the effect of task demand, such as the complexity of the stimulus, also influences attentional processes. Conceptually in Posner and Petersen's model, it is expected that demanding events result in a delay in the disengagement process of the posterior network, followed by a delay in processing new events, thus, producing a delay in orientation and engagement with new stimuli. Effects of stimulus complexity are interesting because the morphology of the P3 response; specifically, the P3 latency is affected by this variable. For example, investigators have suggested that the P3 latency is an index of stimulus evaluation time and is sensitive to the complexity of the stimuli or the demands of the task (Kutas et al., 1977; Polich, 1987).

Further understanding of the relationship between the morphology of the P3 response and attention is significant and leads to this present study. Unlike PET, when stimuli are presented in a nonblocked, eventrelated paradigm, ERPs allow for the separate measurement of activation related to stimulus type (e.g., target, nontarget) as well as the measurement of neural resources allocated during both the motor response and nonmotor response conditions. ERPs also, as noted above, provide an index of stimulus evaluation time.

In the present study, ERPs were obtained during an auditory continuous performance task (A-CPT) under two conditions (motor attention—MA and covert attention—CA). The CPT is a generic term used for a variety of tasks that require sustained attention. It is an established clinical procedure used to detect atten-

tion deficits in patients with neurologic and psychiatric disorders (see, for example, Halperin et al., 1990; Benedict et al., 1998; Parsuraman and Haxby, 1993). The CPT has been studied in our laboratory as well as others in both the auditory and visual modalities (Shucard et al., 1997; Tekok-Kilik et al., 2001 for review). The findings from the Tekok-Kilik et al. (2001) study supported the modality independence of P3. That is, both auditory and visual P3 responses had the same midline scalp topography for target (Go) and specific nontarget (No Go) stimuli. It was concluded that the "cognitive operations required to perform these tasks use neural systems that are independent of modality." The study also showed that the P3 response provides information about the cognitive operations used to perform a task and is consistent with findings obtained with functional imaging studies that have investigated executive systems that control attentional processes, such as target detection and response inhibition.

The CPT differs from the oddball task for which most of the data for P300 have been obtained and it is generally more cognitively challenging than the oddball task. That is, the oddball task has one frequently presented standard stimulus and an infrequent target stimulus (e.g., 80% vs. 20% probability, respectively). Thus, in the classical oddball procedure, only two stimuli require evaluation. In contrast, the CPT such as the one used in the present study requires the evaluation of all stimuli because each stimulus differs from the previous one and only one of multiple stimuli is designated as the target. Thus, the CPT requires more attentional resources to be allocated to the detection of the target than the classical oddball paradigm. Further, stimulus probability does not contribute to increased P3 amplitude to the designated target stimulus in a CPT paradigm such as the one used here as it does in an oddball paradigm. Each of the stimuli, in the present study, had to be closely evaluated to determine whether it was a target, and each nontarget stimulus had a probability that was similar to that of the targets, viz., 11.7% and 18%, respectively. Thus, differences obtained in P3 amplitude between a target requiring a motor response and a target requiring the participant to simply note that it was a target should reflect the differences in resources allocated to the tasks and not probability-related effects based on an attention-drawing oddball stimulus.

The CPT in the present study also allowed for the evaluation of the effects of stimulus complexity and stimulus relevance along with the effects of motor and nonmotor responding. Unlike previous studies, here stimulus complexity (undegraded, degraded syllables) was evaluated within the same conditions (either during MA or CA).

The purpose of the present study was to evaluate the effects of motor and nonmotor responding on P3 amplitude using a CPT paradigm to eliminate the influence of stimulus probability on P3. Also, stimulus complexity was manipulated using degraded and undegraded stimuli within the same condition (MA or CA) to examine the effects on P3 amplitude and latency.

1. Method

1.1. Participants

Twenty-two right-handed undergraduate students, 10 men and 12 women, were included in the final sample. The average age of the participants was 20 years (S.D. = 4.48). All participants were native English speakers, medication-free, and reported no hearing problems and no history of neurological or psychiatric disease. All participants were right handed, as determined by The Handedness Inventory (Briggs and Nebes, 1975), a version of Annett's Hand Preference Questionnaire. The participants were fully informed and gave consent in accordance with the "Ethical Principles of Psychologists" (American Psychological Association, 1992).

1.2. The auditory continuous performance task

Task stimuli consisted of a list of English syllables, voiced by both a male and a female that were binaurally presented one at a time to the participant over headphones. The list of syllables was /ba/, /pa/, /ta/, /da/, /ka/, /ga/, /ma/ and /na/. The target syllable was either a /ba/, /pa/, /ma/ or /da/. The syllables that were never targets and always nontargets were /ta/ and /ga/. A total of 333 syllables were presented in random order that were either undegraded or degraded. The degraded stimuli were muffled by passing the original stimuli through a low-pass filter with a break

frequency of 1150 Hz and a slope rate of 24 dB/ octave. The combined undegraded and degraded target syllables had a probability of 0.18. The combined nontargets had a probability of 0.82. The interval from stimulus onset to stimulus onset was 1200 ms. The syllables were digitized at a rate of 41,000 Hz for a duration of 200 ms. The end points were smoothed using a Hanning Window with a 5-ms rise/fall time. There were two attention conditions: MA and CA.

1.3. Procedure

A practice session was administered before the first CPT to ensure that participants could identify the syllables. During the practice session, degraded and undegraded syllables were presented one at a time over headphones to participants. Participants were required to identify each syllable by pointing to the correct one on a typed page. During testing, participants sat in a recliner in an electrically shielded sound-attenuated chamber. The chamber illumination remained constant throughout the experiment. Prior to electrophysiological recording, participants received a hearing screening. Tone frequencies used for screening ranged from 125 to 8000 Hz with an intensity of 20 dB.

Participants completed the Stanford Sleepiness Scale (SSS; Hoddes et al., 1972) before the beginning of each experimental condition. Measurement of electrode impedance was also obtained before the beginning of each condition and at the end of the study. After the last condition, participants again completed the SSS followed by a questionnaire to obtain information about their perception of the task and their strategies.

Prior to the presentation of MA or CA experimental conditions, and after the practice, participants were asked to listen to the stimuli without responding. This session allowed participants to adapt to the experimental situation and become familiar with the stimulus sequence. It was similar to the Listen-Only (LO) condition in our earlier PET study (Benedict et al., 2002). The MA and CA conditions and the four target syllables were counterbalanced for order such that in a given order, the target for MA was different from the target for CA. The orders of administration of the conditions and the corresponding target syllables are

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shown in Table 1. The nontarget syllables were the same for MA and CA conditions. For the MA condition, participants were instructed to make a bilateral button press on a response pad as quickly and accurately as possible when they detected a target syllable, irrespective of whether it was degraded or undegraded. For the CA condition, participants held the response pad and were instructed to make a mental note of the target syllable, irrespective of whether it was degraded or undegraded or undegraded. All of the participants were told to avoid excessive eye and facial movements. In order to minimize extreme eye movements, participants were instructed to fixate on a disc, 9 cm in diameter, placed 160 cm from the bridge of their nose.

1.4. Electrophysiological and behavioral recording

Grass Instruments gold-plated electrodes were affixed to the participant's scalp with electrode paste, according to the International 10/20 System. Electrode scalp sites included midline (Fz, Cz, Pz, Oz) sites and lateral (F3, F4, C3, C4, P3, P4, T3, T4) sites, all referenced to linked ear leads (A1, A2). A ground electrode was placed on the forehead. Both vertical (VEOG) and horizontal (HEOG) eye movements were recorded. The VEOG electrodes were placed on the supraorbital ridge and 1 cm below the middle of the left eye. The HEOG electrodes were placed on the left and right outer canthi of the eyes. Impedances for scalp electrodes were kept below 10 k Ω .

The EEG data were amplified (7.5 μ V/mm) and filtered with a bandpass of 0.1 to 100 Hz during acquisition. The amplified analog signals were digitized online at a sampling rate of 250 Hz. Continuous EEG from all channels was recorded and stored on a NeuroScan System (NeuroScan, Heardon, VA) for off-line data reduction. Measures of reaction time (RT) to target stimuli were simultaneously obtained during the MA condition.

Table 1

Orders of administration of tasks (motor attention—MA, covert attention—CA) and the corresponding target stimuli (/DA/, /PA/, /MA/, /BA/) $\,$

Order 1		Order 2		Order 3		Order 4	
Task	Target	Task	Target	Task	Target	Task	Target
MA CA	/DA/ /PA/	MA CA	/PA/ /MA/	CA MA	/DA/ /BA/	CA MA	/BA/ /MA/

1.5. Data processing and reduction

The continuous EEG data for each participant were segmented into 1700 ms. The epoch window was set between 300 ms prestimulus and 1400 ms post-stimulus. Data for which participants had errors of omission (misses) and/or commission (false alarms) were excluded from further processing. The remaining data were subjected to a bandpass transformation of 25 Hz (low-pass) and 0.3 Hz (high-pass filter). The resultant waveform was adjusted for DC offset by using the EEG activity in the 300-ms window prior to stimulus onset (baseline activity). For each waveform, the mean DC value was computed using this prestimulus interval. This value was then subtracted from all points within the waveform (baseline correction). The filtered and baseline corrected data were then subjected to artifact rejection procedures which were set at $\pm 200 \ \mu V$ for all scalp sites and $\pm 100 \ \mu V$ for HEOG sites. Vertical eye movement artifact was corrected using the method of Semlitsch et al. (1986).

The EEG for each participant in MA and CA conditions was averaged separately for undegraded and degraded target and nontarget stimuli in the CPT. In order to retain a participant's data, a minimum of 20 acceptable trials was required for each stimulus type (e.g., degraded, undegraded within each condition MA, CA, NT). The mean number of trials across all conditions and stimulus types was 27 (S.D. = 3). The P3 template identification procedure was similar to that used by Tekok-Kilik et al. (2001). The P3 template was identified as the maximum positive deflection (baseline to peak) occurring between 300 and 650 ms. The template was used to define the P3 peak for each individual's averaged waveforms. The P3 response at Fz, Cz, and Pz for MA-target, CAtarget, and NT for both undegraded and degraded stimuli was analyzed for this report.

1.6. Data analysis

Prior to testing the major hypotheses of interest, P3 amplitude and latency for NT stimuli in MA and CA conditions were compared using repeated measures analysis of variance (ANOVA). These analyses showed that there were no significant P3 latency and amplitude differences between undegraded and degraded NT stimuli for both MA and CA conditions and no differences between MA undegraded and CA undegraded or MA degraded and CA degraded for NT stimuli. Thus, the NT values for MA undegraded and CA undegraded were combined to yield NT undegraded values. Similarly, the NT values for MA degraded and CA degraded stimuli were combined to yield NT degraded values. These combination scores defined the NT stimulus condition and were used in subsequent analyses. To test the major hypotheses related to motor response, attention, and stimulus complexity, separate repeated measures analyses of variance (ANOVAs) were performed on P3 amplitude and latency values obtained from the midline electrodes. The specific analysis was: Stimulus Type (MA-target, CA-target, NT) \times Stimulus Complexity (undegraded, degraded) \times Lead (Fz, Cz, Pz). Simple effects comparisons were performed using one-way ANOVA. Even though order was experimentally controlled through counterbalancing, the analysis of order effects was performed to statistically determine whether the order of MA and CA had any effect on the P3 to MA-target and CA-target stimuli. The effect of order was analyzed using one-way betweensubjects ANOVAs. One-way repeated measures ANOVAs were performed to test possible differences in RT to undegraded and degraded target syllables during the MA condition.



Fig. 1. Grand averaged ERPs for undegraded and degraded stimuli for MA-target, CA-target, and NT.

The results were evaluated using Greenhouse– Geisser values, when appropriate, to adjust for the possible violation of sphericity related to repeated measures ANOVA. All analyses were conducted using SPSS for Windows.

2. Results

2.1. P3 amplitude effects

The analysis of order of presentation revealed that P3 amplitude for MA-target and CA-target was not affected by order (p>0.05, n.s.). Thus, order was not considered to be a factor in subsequent analyses. Fig. 1 presents the ERP grand averages for undegraded and degraded stimuli across all stimulus types. The analysis of P3 amplitude effects (Stimulus Type × Sti-Stimulus Complexity × Lead ANOVA) yielded a significant Stimulus Type (MA-target, CA-target, NT) × Lead (Fz, Cz, Pz) interaction, $F_{(4,84)} = 25.14$, p < 0.01. Analyses of the simple effects using one-way ANOVAs showed that P3 amplitude was greater for MA-target than CA-target at all leads (Fz, Cz, Pz; p < 0.01), irrespective of whether the target was degraded or undegraded; however, CA-target elicited greater P3 amplitude than NT at Pz and at Cz (p < 0.01), but not at Fz. These findings are illustrated in Fig. 2.

One-way within-subjects ANOVA for lead revealed that the expected anterior-posterior scalp topography for P3 amplitude was observed for all three stimulus types (MA, CA, NT) with the highest amplitude at Pz (Pz>Cz>Fz, p<0.01). Although MAtarget had greater amplitude than CA-target at all leads, both elicited the expected parietal-maximum P3 amplitude for target stimuli. As indicated, the P3 topographical distribution seen for target stimuli also was similar for nontarget stimuli (Pz>Cz>Fz, p < 0.01) but the P3 amplitude for NT was lower relative to the P3 for MA-target and CA-target conditions (see above and Figs. 1 and 2). This finding suggests that although the participants attended to all stimuli during MA and CA conditions, the neural resources allocated among stimulus types (MA-target, CA-target, NT) differed significantly. As noted, this allocation of resources, indexed by P3 amplitude, was independent of the effect of stimulus complexity (degraded, undegraded).

2.2. P3 latency effects/behavioral measures

The analysis of P3 latency effects (Stimulus Type-× Stimulus Complexity × Lead ANOVA) yielded a significant Stimulus Type (MA-target, CA-target, NT) × Stimulus Complexity (undegraded, degraded) × Lead interaction, $F_{(4,84)}$ =3.64, p <0.01. The latency values are presented in Table 2. Analysis of the simple effects revealed that P3 latency for the degraded stimuli was longer than P3 latency for the undegraded stimuli at Pz for MA-target, $F_{(1,21)}$ =9.12, p <0.01, and at Fz for CA-target, $F_{(1,21)}$ =7.47, p <0.01. Also, comparisons of interest between MA and CA showed that CA-targets had longer latency



Fig. 2. Mean amplitudes for MA-target, CA-target, and NT at each lead. Significant stimulus type by lead interaction (p < 0.01).

Motor a	attention				Covert at	tention			Non-targ	ets		
Lead Unde Mean	Undegrade	d	Degraded		Undegraded		Degraded		Undegraded		Degraded	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Fz	437.4	79.1	442.6#	92.0	448.6^{+}	76.3	494.2 ^{#, +}	67.4	456.1	55.4	455.6	54.2
Cz	437.7	75.1	467.9	82.3	473.0	84.0	502.0	71.4	460.9	53.2	462.3	45.8
P ₇	441 3* ^{,‡}	82.1	496.0*	86.7	$484\ 2^{\ddagger}$	83.7	521.1	53.2	469 9	59.1	471.8	57.9

Table 2 Means and standard deviations of P3 latencies to targets and non-targets during motor attention (MA) and covert attention (CA) conditions

*Degraded MA>undegraded MA, p < .01.

[#] Degraded CA>degraded MA, p < .05.

⁺ Degraded CA>undegraded CA, p < .01.

[‡] Undegraded CA>undegraded MA, p < .05.

than MA-targets for undegraded stimuli at Pz and longer latency than MA-targets for degraded stimuli at Fz ($F_{(1,21)} = 4.38$, p < 0.05 undegraded; $F_{(1,21)} = 4.47$, p < 0.05 degraded). There were no differences between NT degraded and undegraded stimuli. Although there appears to be a general increase in P3 latency associated with stimulus complexity within each condition, this effect is condition and lead dependent. As noted, the effects of stimulus complexity on P3 latency for targets are seen at the parietal scalp site for MA and at the more anterior scalp sites for CA. Stimulus complexity, additionally, had an effect on reaction time measures obtained for MA-target. The degraded target syllables showed a significantly longer reaction time than the undegraded target syllables (mean = 0.56 s, S.D. = 0.08, mean = 0.53 s, S.D. = 0.07, respectively; $F_{(1,21)} = 14.72, p < 0.01$).

3. Discussion

The present study examined the effects of attention, motor responding, and stimulus complexity on the P3 amplitude, topography, and latency under two target conditions (MA, CA) and two levels of stimulus complexity (undegraded, degraded). The data showed that for both conditions, target stimuli produced a maximum relative P3 amplitude at the posterior scalp site (Pz). This finding suggests that the participants attended to and evaluated the stimuli, irrespective of motor or covert responding. Although the NT condition produced a similar posterior-maximum P3 topography, both MA-target and CA-target had greater P3 amplitudes than NT at Pz. These amplitude and topographical relationships support the data we obtained in the PET study for a smaller sample (Benedict et al., 2002).

The findings in this present study are consistent with the notion that participants were consciously attending to and evaluating all of the CPT stimuli; however, more attentional resources were allocated to targets than nontargets, regardless of whether or not a motor response was required. Further, the target during the MA condition produced greater P3 amplitude responses than during the CA condition, as previously reported (Benedict et al., 2002). These results suggest that the requirement of a motor response increases the neural resources allocated to the task and that the P3 amplitude is an index of these resource demands.

Interestingly, stimulus complexity did not affect P3 amplitude but complexity effects were observed for the P3 latency and reaction time measures. The target P3 latencies and reaction times were generally longer for the degraded syllables than for the undegraded syllables, suggesting longer stimulus evaluation and response times for the more complex stimuli. However, the differences between P3 latencies for undegraded and degraded syllables varied across leads and conditions. When the participants were required to make a motor response (MA-targets), the P3 latency for degraded syllables was longer than for the undegraded syllables and was statistically significant only at the posterior scalp site (Pz). On the other hand, the latency was significantly longer for the degraded or more complex stimuli at the frontal location (Fz) when no motor response was required (CA condition).

The latency differences produced by stimulus complexity between MA-targets and CA-targets suggest that the CA condition may have allowed participants more time than the MA condition to categorize the syllables (target or nontarget). During the CA condition, participants were instructed to make a mental note upon detection of a target stimulus. For the MA condition, participants were instructed to press as quickly and accurately as possible when a target stimulus was detected. Thus, instructions for the CA condition did not impose an urgency to respond as did instructions for MA. In addition, since the decision to respond did not require as precise an end point as in MA, the P3 latency across single trials was likely more variable for CA-targets than MA-targets, thereby leading to a lower overall amplitude and longer latency response to degraded targets during CA than MA.

The significant difference in latency between undegraded and degraded target stimuli at the posterior site for the MA condition suggests that the need to respond "quickly" adds to the demands required of the participant and may have resulted in increased recruitment of the posterior attentional network by the anterior network. This recruitment of the posterior network by the anterior network agrees with the notion that there is communication between the two attention networks, and that there is a hierarchy of attention systems in which the anterior network asserts control over the posterior network for additional processing of information (Goldman-Rakic, 1988; Posner and Petersen, 1990). Thus, this increased posterior recruitment may provide a possible explanation for the longer latency for degraded than undegraded target stimuli observed at the posterior site during the MA condition. An increase in single trial latency variability related to processing more complex stimuli (degraded) may have also attenuated (relative to undegraded stimuli) the posterior P3 amplitude for the degraded stimuli. This " latency jitter" may have prevented the expected increase in P3 amplitude that normally accompanies increased resource allocation.

The P3 latency results of the present study are supported by previous reports. Kutas et al. (1977) found that more difficult to interpret stimuli did not affect P3 amplitude but resulted in longer P3 latency, suggesting that these stimuli require longer evaluation time. Polich (1987) also reported that more difficult to process stimuli result in longer P3 latency and attenuated P3 amplitude. The attenuated amplitude that was found by Polich (1987) may not have been a direct effect of stimulus complexity but rather to the inverse relationship between P3 latency and P3 amplitude (i.e., longer latency, smaller amplitude; Kok, 2001) or to increased single trial latency variability.

The difference in the neural resources allocated for MA-target and CA-target seen in ERP and PET can be clarified further by analyzing the cognitive and behavioral operations required for each of the conditions. As seen in Table 3, these operations suggest that the neural resources allocated to MA-target and CAtarget stimulus types, as indexed by P3 amplitude, should differ. The P3 amplitude difference between MA-target and CA-target is due, at least in part to "motor preparation" (Kok, 1988). Kok (1988) stated that "motor preparation" related to motor responses during conscious attention conditions affects P3 amplitude. The results of our study convincingly demonstrated that P3 amplitude is affected by both target detection and the response requirements.

In conclusion, this study demonstrated that covert attention to a target can elicit a P3 response without the requirement of counting or responding motorically to targets. Further, the CPT task used in the present study, unlike an oddball paradigm, eliminates the contribution of stimulus probability effects on P3 amplitude, thus strengthening the evidence for the hypothesis that the covert attention to the designated syllable (target) in an array of syllables produced a significant P3 response. This study provided evidence that participants were attending to and detecting the stimuli and that P3 obtained without a motor response is a reliable index of focused attention. Furthermore, our results show that the physiology of attention can be assessed with a paradigm that does not require a motor response. The use of a CA task is desirable in studies involving clinical populations in which the requirement for a motor response either may not be possible or may confound neurophysiological and functional

Table 3

Cognitive and	behavioral	operations	related	to	Р3	amplitude
0						

Stimulus type	Target anticipation	Stimulus evaluation	Target recognition	Motor preparation
MA-target				
CA-target				
NT				

The P3 amplitude for MA-target differed from CA-target and NT in that it was also affected by motor responding.

data. In addition, the method used in the present study is useful for imaging and electrophysiological investigations of neural attentional networks associated with specific cognitive functions such as target detection without the added variability of motor activity.

Acknowledgements

This research was supported in part by a research grant from the James H. Cummings Foundation. We thank Dr. James Sawusch for the preparation of the stimuli and Jeremy Savage for his technical assistance.

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