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Examining the Relationship between Self-Efficacy and Stimulus processing

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Abstract

Stimulus processing is an essential cognitive process that plays a vital role in our decision making and task execution. Since stimulus processing has been shown to be an important factor in task performance and cognitive well-being, it is necessary to explore the relationship it has with other psychological variables related to performance, as well as assess ways in which stimulus processing may be enhanced. The authors hypothesized that self-efficacy (SE) may improve performance by enhancing stimulus processing during task completion. To test this hypothesis, we examined the relationships between SE, behavioral measures of task performance, and neural indices of stimulus processing during the completion of two sessions of a modified flanker task. The first session was completed to determine if SE was related to neural indices of stimulus processing while the second session was included to examine whether alterations in SE would lead to corresponding alteration in stimulus processing. In total, 76 healthy young adults completed the experiment and were exposed to either, false positive (24), false negative (26), or no performance (26) feedback after the first session to alter their task SE. Behavioral measures included response accuracy and response time (RT), and neural indices included the P3b, an event-related brain potential associated with stimulus processing. Results showed that higher SE was associated with greater response accuracy and P3b amplitude during task execution in the first session. After SE manipulation, results indicated a significant effect of the feedback manipulation on SE, but no significant influences on P3b, accuracy, reaction time, or changes in those measures across sessions. These findings suggest that SE is beneficially related to neural indices of stimulus processing, and improved stimulus processing may help explain the association between SE and improved task performance. However, our specific manipulations of task-related SE are not sufficient to significantly improve subsequent stimulus processing.

Examining the Relationship between Self-efficacy and Stimulus Processing

Every second of every day, the normal human brain is continuously attending to, and processing, stimuli whether we are conscious of it or not. Some stimulus processing is simple, such as distinguishing novel objects or conditions. Other stimulus processing can be much more complex and involve attending to several different stimuli, or aspects of stimuli, at once (Polich, 2007). The more complex processing involves allocating attentional resources to all aspects of the stimulus or stimuli in order to fully process the situation. The way a stimulus is processed is an essential part of decision making and task execution. Individuals who show deficits in stimulus processing often cannot efficiently make correct decisions and their performance during task execution suffers (Bestelmeyera, Phillips, Crombiec, Benson, & St.Clairc, 2009; Bramon, Croft, Arthur, McDonald, Frangou, & Murray, 2003; Justus, Finn, & Steinmetz, 2001). Since stimulus processing has a direct effect on task performance, it is important to explore this concept to determine its underlying components and assess ways in which stimulus processing may be enhanced.

Neuroelectric Components of Stimulus Processing

One way in which stimulus processing can be measured is through electrophysiological means. Neuroelectric activity occurs continuously during the completion of cognitive tasks and neuroelectric measurement provides a sensitive assessment of cognitive processing. The form of neuroelectric measurement that is most appropriate for measuring stimulus processing involves the use of event-related brain potentials (ERPs). ERPs are records of electrocortical activity evoked by physical stimuli and modulated by psychological processes such as attention, memory, and cognition. One measure of neuroelectric activity that has captured quite a bit of attention in the literature as an index of stimulus processing is the P300. The P300 is a component of an endogenous ERP that is characterized as a positive deflection in an ERP that peaks approximately 300-1000ms after stimulus onset (Sutton, 1965) and is most positive at central and parietal locations (Fabiani, Sadler, & Wessels, 2000). The P300 has been examined most commonly in studies involving simple discrimination tasks, and is believed to reflect neuronal activity that is deeply involved with basic cognitive functions like memory updating and attentional resource allocation (Brumback, Low, & Gratton, 2005; Donchin, 1981; Polich & Kok, 1995). There are two variations of the P300, the novelty P3a and the classical P3b. The P3a is elicited only in response to novel stimuli and has a faster peak latency in comparison to the P3b. Conversely, the P3b is only elicited in response to task-relevant stimuli during target stimulus processing and has a slower peak latency than the P3a (Snyder & Hillyard, 1976; Squires, Squires, & Hillyard, 1975). The current study will be focusing on the P3b, which can be subdivided and examined according to its peak amplitude and latency.

The amplitude of the P3b is measured as a positive change in voltage after the N1-P2-N2 complex, which is a series of multiple ERP components related to attentional orientation, and increases in magnitude from frontal to parietal electrode sites (Johnson, 1993; Polich & Kok, 1995). P3b amplitude is thought to reflect changes in the neural representation of the stimulus environment and is proportional to the amount of attentional resources needed to engage a given stimulus or task, with larger (more positive) P3b amplitudes associated with greater attentional allocation (Polich & Heine, 1996). P3b latency is the time from stimulus onset to the maximum positive amplitude within a specified latency window. Like peak amplitude, peak latency increases from frontal to parietal electrode sites (Polich et al., 1997; Polich & Kok, 1995), and is thought to index classification speed, which is proportional to the time required to detect and evaluate a stimulus and is sensitive to task processing demands and individual differences in cognitive ability (Kutas, McCarthy, & Donchin, 1977; Magliero, Bashore, Coles, & Donchin, 1984; Polich, 2007). Generally, the P3b is influenced by the cognitive demands during task processing (Polich, 2007), thus the elicitation and generation of the P3b component is a constant and ongoing process that is influenced by a number of factors. These influencing factors on the P3b generally fall into four categories: internal, external, static and modifiable.

External influences. External influencing factors are those factors that arise from sources outside the individual. A large literature exists documenting the effects of external factors on the P3b. The original P3b studies manipulated stimulus information to assess how patterns of brain activation varied among task conditions. These manipulations included basic variations of the oddball task where a mental or physical response to a target elicits the P3b (Polich & Criado, 2006). The results provided evidence that subjective probability and task relevance of a stimulus influence P3b amplitude, with less frequently occurring and more relevant stimuli eliciting larger P3b amplitudes (Donchin, 1981). These target stimulus effects served as the basis for the suggestion that the P3b originates from task conditions involving working memory and that conscious awareness is required to elicit a P3b (Donchin, Karis, Bashore, Coles, & Gratton, 1986). Supporting this claim, Melloni and colleagues (Melloni, Molina, Pena, Torres, Singer, & Rodriguez, 2007) found that only conscious perception of stimuli evokes the P3b, with no similar response to subliminal stimuli. Additionally, studies utilizing dual task paradigms have elicited a P3b to both primary and secondary tasks, but the amplitude associated with the secondary task decreases as the primary task difficulty increases, showing further evidence for the relationship between P3b and the expenditure and distribution of attentional resources (Wickens, Kramer, Vanasse, & Donchin, 1983). Finally, a P3b is elicited for every trial during the execution of a common interference control task known as the Eriksen flanker task (Eriksen & Eriksen, 1974). Yet smaller P3b amplitudes have been found during incongruent, rather than congruent, task conditions, implicating the increased attentional demand for interference control in the more difficult incongruent task condition for the reduction in attentional allocation to stimulus processing (Hillman, 2004). Thus, evidence from studies involving external influencing factors on the P3b indicate that the P3b is a consciousness-dependant ERP component that is sensitive to task difficulty, as well as the subjective probability of task stimuli or conditions, and indexes the allocation of attentional resources to external stimuli which is required for the proper execution of a task (Donchin, 1981; Hillman, 2004; Polich & Criado, 2006; Wickens et al., 1983).

Internal influences. While a large literature exists detailing external influences on P3b amplitude and latency, significantly less research has examined internal influences on the P3b. Internal influences are those factors derived from within the individual; examples of these factors include static or stable individual difference variables such as personality traits or cognitive health status. Research has supported modest associations between personality attributes and the P3b. For example, a positive relationship exists between the P3b and extraversion, openness, agreeableness, and conscientiousness while a negative relationship exists between the P3b and neuroticism (Gurrera, O'Donnell, Nestor, Gainski, & McCarley, 2001). Intelligence has been investigated for a potential relationship with the P3b and evidence suggests that grade point average is correlated negatively with P3b latency (Polich & Martin, 1992). Sensation seeking and impulsivity are also positively related to the P3b (Stelmack & Houlihan, 1994) and arousal has been examined in relation to the P3b, with high arousal individuals having larger amplitudes compared to those with low arousal (Brocke, 2004). The relationship between P3b and personality attributes is thought to be modulated by biological factors (Polich & Kok, 1995), differences among experimental designs and task paradigms (Stenberg, 1994), psychopathology (Justus et al., 2001), and could be related to individual differences for attentional resource capabilities that may stem from variability of neurotransmitter function (Polich & Criado, 2006). Therefore, although evidence exists showing a relationship between P3b amplitude and these static individual differences, not much is known about the underlying factors behind these relationships and what may be done to improve stimulus processing as indexed by P3b amplitude.

Additional internal influences on the P3b amplitudes have been related to biological sources. The P3b's characteristics are genetically transmitted (van Beijsterveldt & van Baal, 2002) and are highly similar between family members (Eischen, Luckritz, & Polich, 1995) and even stronger between identical twins (Stassen, Bomben, & Propping, 1987). Cognitive decline due to aging is related to P3b, where the amplitude decreases and latency increases at a steady rate as age increases (Polich et al., 1985). Reduced P3b amplitude has even been associated with antisocial, defiant, and impulsive traits which can be related to vulnerability to alcoholism (Justus et al., 2001). The amplitude of the auditory P3b is reduced in patients with axes I and II disorders (Gurrera et al., 2001) and specific research has found a substantial decrease in P3b amplitude in individuals with psychotic bipolar disorder and schizophrenia (Bestelmeyer et al., 2008; Hall et al., 2009; Justus et al., 2001). In fact, because cognitive impairment is often correlated with modifications in the P3b waveform, the waveform can be used as a measure for the efficacy of various treatments on cognitive function. This indicates that perhaps proactive modification of the P3b can subsequently positively impact cognitive impairments. In spite of this developing literature exploring internal influences on the P3b, little research has been found on internal individual difference variables that can be manipulated to positively affect the P3b and task execution.

Modifiable influences. One modifiable individual difference variable that has been related to the P3b is physical activity. Physical activity has been shown to affect the P3b amplitude, with active individuals exhibiting increased P3b compared to their sedentary counterparts (Polich & Lardon, 1997); this suggests that fitness can improve the attentional system that contributes to the P3b. Evidence also suggests that aging-related cognitive decline may stem, in part, from atrophy of the neural network involved in attentional control (Milham et al., 2002). Physical fitness, though, may protect against cognitive aging and can decrease the negative effects of aging on P3b amplitude and task performance by strengthening the attentional systems (Pontifex, Hillman, & Polich, 2009). However, there are limitations to the positive influence physical activity may have on the P3b. Fitness may not be sufficient to overcome deficits in stimulus discrimination with increases in task difficulty (Pontifex et al., 2009). Additionally, some individuals cannot regularly engage in physical activity or fitness-related behaviors due to health conditions and limitations, or may not have access to the fiscal resources needed to regularly participate in supervised exercise or fitness programs. Physical fitness is also not an easy factor to modify. Substantial alterations in fitness may only be evidenced following an extended activity program and participant dropout is always a significant concern for such interventions (Ryan, Frederick, Lepes, Rubio, & Sheldon, 1997; Stiggelbout, Hopman-Rock, Tak, Lechner, & van Mechelen, 2005). Accordingly, other modifiable means of altering the P3b need to be investigated.

Self-efficacy

One modifiable psychosocial factor that may be related to alterations in the P3b is self-efficacy (SE). SE is an internal individual difference variable and SE expectations reflect individuals' beliefs in their capabilities to successfully complete courses of action (Bandura, 1977) and are theorized to influence task choice, effort expenditure, and perseverance under aversive stimuli and failure (Bandura, 1986). SE is positively associated with work-related performance and cognitive task performance (Bouffard-Bourchard, 1990; Stajkovic & Luthans, 1998) and evidence suggests that SE plays an important role in achievement and self-regulatory adjustments during challenging tasks or task conditions. Experimentally-induced SE expectations have also been related to cognitive task performance, where increased SE leads to better performance (Bouffard-Bouchard, 1990). This effect of SE on cognitive task performance is believed to exist, in part, because of an increase in cognitive processing. Berry (1987) found that the more confident individuals were in their memory capabilities, the more effort they devoted to cognitive processing of memory tasks. This higher cognitive effort, in turn, produced better performance. This relationship between SE and cognitive effort, as well as task performance, suggests that SE may affect the underlying mechanisms involved in these processes, and ultimately provide evidence that SE may improve stimulus processing as well.

SE can be manipulated with relative ease through a variety of means, including social persuasion as well as both mastery and vicarious experiences (Bandura, 1986). In pursuing goals or achieving certain levels of competence, people receive feedback concerning their performance. The way in which progress is evaluated by an individual can strongly effect SE appraisal and alter subsequent performance. Performance feedback that focuses on achieved progress underscores personal capabilities, and feedback that focuses on shortcomings highlights personal deficiencies (Bandura, 1993). Accenting gains achieved enhances perceived SE, aspirations, self satisfaction, and performance accomplishments, whereas highlighting deficiencies undermines self-regulative influences, resulting in deterioration of performance (Jourden, 1992).

SE can also be modified through means of social comparisons (Bandura, 1993). Comparisons like grading practices and teacher evaluations on performance have a great impact on the SE of students (Marshall & Wienstein, 1984; Rosenholtz & Simspon, 1984). Social comparison affects performance through its impact on self regulatory mechanisms. Seeing oneself surpassed by others undermines SE and impairs performance attainment. In contrast, seeing oneself gain mastery over others boosts SE and enhances performance (Bandura & Jourden, 1991). For example, McAuley, Talbot, and Martinez (1999) used a bogus feedback method in which the participants were told they were in the top 20th percentile or bottom 20th percentile of all others in their age group to effectively alter participants' SE either positively or negatively to ascertain a relationship between SE and feeling states.

One important similarity among the above mentioned studies that examine SE is that they only incorporate behavioral measures. However, research has shown that neural measures of cognitive processes are sensitive to variations in SE as well. Specifically, researchers examined the relation between self-regulatory action monitoring processes and SE expectations in older adults (Themanson et al., 2008). They found that more efficacious individuals exhibit larger error related negativity (ERN) and error related positivity (Pe) amplitudes compared to low-SE individuals during the completion of a cognitive task that emphasized the accuracy of performance. Additionally, larger (more negative) ERN amplitude was associated with greater post-error accuracy in the high-SE group. This suggests that SE may be related to neuroelectric indices of task-relevant cognitive processing when a task demands high performance.

Present Study

Because SE has been shown to be related to task performance as well as neural indices of cognitive processing, it is hypothesized that SE will be related to the P3b. Specifically, it is predicted that individuals with greater SE will not only show superior task performance (greater accuracy) relative to those individuals with lower SE, replicating previous research findings, but will also show larger P3b amplitudes during cognitive task completion, suggesting enhanced stimulus evaluation during task execution. Further, when SE is manipulated, both task performance and the amplitude of the P3b will mirror that manipulation, suggesting that alterations in SE may lead to alterations in task performance and stimulus processing. If the P3b is related to task performance, and the manipulation of SE results in a similar manipulation of the P3b, this study would provide evidence for a proactive method for positively modifying attentional allocation and task performance through the enhancement of stimulus processing during task execution. By exploring this relationship further, findings from the present study may deepen the understanding of the function of this ERP component, enhance existing theories on the P3b, and provide evidence for a methodology that would allow individuals to improve their stimulus processing and subsequent behavioral interactions with the environment.

Methods

Participants

Eighty-seven healthy adults (18-25 years) were recruited from the undergraduate population at Illinois Wesleyan University. Participants fulfilled a General Psychology course requirement in exchange for their participation. The participants were randomly assigned to one of three experimental groups: a high efficacy manipulation group (n = 24), a low efficacy manipulation group (n = 26), or a no efficacy manipulation control group (n = 26). Eleven participants were excluded due to either excessive artifact in their neuroelectric data or not performing the cognitive task at or above 50% accuracy in each task condition. The study was approved by the Institutional Review Board at Illinois Wesleyan University.

Assessments, Measures, and Experimental Manipulations

Cognitive task. Participants completed a modified version of the Eriksen flanker task (Eriksen & Eriksen, 1974) which has previously been associated with the P300 and a neural network involved in the executive control of attention through neuroimaging research (Bush, Luu, & Posner, 2000). The flanker task has frequently been used to test an individual’s ability to manage interference from task-irrelevant information in the stimulus environment through examining comparisons of the responses to the congruent versus incongruent stimuli (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Congruent stimuli elicit faster and more accurate responses, whereas incongruent stimuli elicit increased errors rate and decreased response speed because they result in greater response competition (Spencer & Coles, 1999). The participants were asked to respond to a series white stimuli presented on a computer screen with a black background. Specifically, four distinct stimuli were presented to the participants (congruent: <<<<< or >>>>>; or incongruent: <<><< or >><>>) and participants were asked to respond to the direction of the central symbol by pressing a keypad with their thumbs. A target symbol pointing to the right (>) required a right-handed response and a target symbol pointing to the left (<) required a left-handed response. The stimuli were viewed on a computer monitor at a distance of 1m and each array of symbols subtended 13.5° of the horizontal visual angle and 3.4° of the vertical visual angle when presented on the screen. The stimuli were 4 cm in height and appeared on the screen for 80 ms with an inter-stimulus interval varying between 1000, 1200, and 1400 ms in order to prevent expectancy bias. Congruent and incongruent trials were equiprobable and randomly ordered within each task. For each session the task was grouped into two task blocks of 300 trials each, with a brief rest period between each block. The order that the blocks were given were counterbalanced across participants and across sessions. The participants were asked to respond as quickly and accurately as possible to all of the trials.

Self-efficacy assessment. The measure that was constructed to assess SE for performance on the cognitive task followed the format recommended by Bandura (1977) and has been used in previous research (Themanson et al., 2008). Participants were asked to report their degree of confidence in accurately completing trials. The measure consisted of 10 items on the scale that reflected beliefs relative to the accurate completion of successively more trials on the flanker task. The first item on the scale read, “I believe that I am able to accurately complete 10 out of 100 trials.” Each successive item on the scale increased by 10 trial increments, up to the last item which examined the beliefs relative to completing 100 out of 100 trials. Each item was scored on a scale from 0% to 100%, where 0% represented “not at all confident” and 100% represented “highly confident.” Responses to all 10 items were summed and divided by the total number of items to obtain an efficacy score with a possible range from 0-100.

Self-efficacy manipulation. As previously stated, participants were randomly assigned to either a high-efficacy (HE) feedback group, a low-efficacy (LE) feedback group, or a no-efficacy (NE) feedback group. Upon completion of the first two blocks of 600 trials on the first day, participants were given bogus feedback relative to their performance. Participants in the HE group were informed that their task performance placed them in the top 20th percentile based on performance norms of their college-aged peer group. Conversely, participants in the LE group were told that their performance was in the bottom 20th percentile for the task based on college-aged peer group performance norms. Finally, the participants in the NE, or control, group did not receive any exposure to these documents or the false feedback protocol. Performance feedback came in the form of several computerized spreadsheet documents that the participants were told was a reflection of their actual performance. The first document contained a numerical summary of how many correct responses the participant gave and his/her numerical percentage of correct responses compared to percentage of correct responses for the college-aged norm. The second document was a bar graph representing the participant's performance in comparison to all others their age. The third document was a normal curve with a z-score that represented the performance of the participant. Along with the normal curve, a vertical line was displayed that "placed" the participant at either the top 20th percentile for the HE group, or the bottom 20th percentile for the LE group. A research assistant walked each participant through each document and explained what each chart and graph meant in depth. A manipulation technique similar to this one has been utilized in previous research (McAuley et al., 1999).

Neural assessment. The electroencephalogram (EEG) was recorded from 64 sintered Ag-AgCl electrodes (FPz, Fz, FCz, Cz, CPz, Pz, POz, Oz, FP1/2, F7/5/3/1/2/4/6/8, FT7/8, FC3/1/2/4, T7/8, C5/3/1/2/4/6, M1/2, TP7/8, CB1/2, P7/5/3/1/2/4/6/8, PO7/5/3/4/6/8, O1/2) embedded in an elastic cap, arranged in an extended 10–20 system montage with a ground electrode (AFz) near the frontal sites. The sites were referenced online to a midline electrode placed at the midpoint between Cz and CPz. Bipolar electrooculographic activity (EOG) was recorded to monitor eye movements using sintered Ag-AgCl electrodes placed above and below the right orbit and near the outer canthus of each eye. Impedances were kept below 10 Ω for all electrodes. A Neuroscan Synamps2 bioamplifier (Neuro Inc., El Paso, TX), with a 24 bit A/D converter and +/- 200 millivolt (mV) input range, was used to continuously digitize data at a sampling rate of 500Hz, amplified gain of 10 with a DC to 70Hz filter, and a 60 Hz notch filter.

EEG activity was recorded using Neuroscan Stim (v 4.3.1) and stimulus presentation, timing, and measurement of behavioral response time and accuracy were controlled by Neuroscan Stim (v 2.0) software.

Offline EEG processing included eye blink correction using a spatial filter (Compumedics Neuroscan, 2003), re-referencing to average mastoids and merging with behavioral data. The stimulus-locked component included the creation of epochs from -100-1,000 ms around stimuli and baseline correction using the 100-ms prestimulus period. Data were filtered with a 30-Hz low-pass cutoff, and artifact detection excluded trials with amplitudes ± 75 μV. Artifact free data were averaged. The P3b was defined as the largest positive-going peak within a 300-700ms latency window following stimulus presentation. Amplitudes were measured as a change from prestimulus baseline, and peak latency was defined as the time point of the maximum peak amplitude.

Procedure

The general procedure for this study was divided into two days. On the first day (D1), after providing informed consent, participants completed: a brief demographics questionnaire, the Edinburgh handedness inventory (Oldfield, 1971), a personality inventory developed from International Personality Item Pool scale (IPIP; Goldberg, 1999) and the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990). The K-BIT was administered by a trained research assistant. Participants were then seated in a comfortable chair 1m in front of a computer screen and prepared for neural measurement in accordance with the guidelines of the Society for Psychophysiological Research (Picton et al., 2000). After acceptable EEG signals were observed, the participant was briefed on how to properly complete the flanker task. The lights were dimmed and the participants were administered 20 practice trials under instructions to respond as accurately as possible to familiarize them with the task. Following the practice trials, participants completed the SE measure to assess expectations relative to their performance on subsequent trials of the task. The participants were then given two blocks of 300 trials each, with a brief rest provided in between the task blocks. After the completion of both blocks the participants were shown the bogus feedback to which they were assigned. After the feedback was given the participants were asked again to complete the SE questionnaire. If they were in the group that received no feedback they were given the SE questionnaire immediately following the completion of the second task block and were dismissed for the day. This session lasted approximately 120 minutes.

On the second day (D2), the participants returned to have their behavioral and neural measures collected during the completion of the task. The participants were once again seated in the same position in front of the computer and prepared for neural measurement. After the completion of a practice session of 20 trials, the participants were shown the bogus feedback they had received during the D1 session, the meaning of the feedback was summarized once again for the participants, and the SE measure was administered. After finishing the SE measure, the participants completed two blocks of the flanker task. Following the completion of the last task block, the participants were given a final SE questionnaire and debriefed on the deceit procedures and purpose of the experiment. This session lasted approximately 60 minutes.

Results

Self-efficacy

The mean (± SD) SE score was 73.0 (±15.9) with scores ranging from 28 to 98 on a scale with a possible range of 0 to 100. No significant correlations were present between SE and any demographic factors, including sex, age, or any personality factors. However, significant correlations were present between SE measures and IQ, (r = .28, p < .05), with higher IQ associated with greater SE.

Behavioral Task Performance

A paired samples *t*-test was performed to compare the means of congruent and incongruent trials and behavioral task performance. When compared, the mean accuracy for congruent trials (M = 93.8, SD = 6.1), was significantly higher from the mean accuracy for incongruent trials (M = 84.2, SD = 7.6), $t(75) = 16.6$ $p < .001$. Additionally, the mean reaction time (RT) for congruent trials (M = 378.3, SD = 48.2), was significantly faster from the mean RT for incongruent trials (M = 441.1, SD = 53.6), $t(75) = 29.1$, $p < .001$. As expected, these results demonstrate that the participants performed with greater accuracy and faster RT on congruent trials than for incongruent trials.

A significant correlation was present between overall accuracy and SE, (r = .39, p < .01), with greater SE associated with greater response accuracy (see Figure 1). Specifically, correlations were present between SE and accuracy on congruent trials, (r = .35, p < .01), as well as incongruent trials, (r = .38, p < .01), suggesting that higher SE is associated with greater task accuracy regardless of trial type. Accuracy was also significantly correlated with IQ, (r = .30, p < .01). Thus, a hierarchical regression analysis was conducted to assess the relationship between SE and accuracy by regressing accuracy on IQ entered as a covariate in the first step, and SE entered in the second step of the analysis. The overall regression model was significant (R^2 = .16 $F_{(2,73)}$ = 7.1, p = .001) with the expected significant effect for IQ in the first step of the analysis as well as a significant effect for SE in the second step of the analysis, (ΔR^2 = .12, $F_{(1,73)}$ = 10.3, p =.002), suggesting that SE has a unique association with accuracy above and beyond the relation between accuracy and IQ. Table 1 provides a summary of this regression analysis.

A significant correlation was also present between RT and SE, (r = -.25, p < .05), with greater SE associated with faster RT (see Figure 2. 2). Specifically, correlations were present between SE and RT on congruent trials, (r = -.24, p < .05), as well as incongruent trials, (r = -.28, p < .05), suggesting that higher SE is associated with faster RT regardless of trial type. Reaction time was also significantly correlated with age (r = -.25, p < .05) and IQ (r = -.32, p < .01). Thus, to assess the relationship between SE and RT, a hierarchical regression analysis was conducted regressing RT on age and IQ entered as covariates in the first step, and SE entered in the second step. The overall regression model was significant (R^2 = .13, $F_{(2,73)}$ = 5.49, p < .01) and revealed a significant effect for IQ in the first step of the regression. However, no significant influences were present for age in the first step or SE in the second step, (ΔR^2 = .03, $F_{(1,72)}$ = 2.4, p = .13), of the regression, suggesting that SE is not uniquely associated with RT. Table 1 provides a summary of this regression analysis.

P3b

P3b amplitude. The omnibus 2 (condition: congruent, incongruent) × 7 (site: Fz, FCz, Cz, CPz, Pz, POz, Oz) mixed model ANOVA revealed two main effects of condition, $F_{(1,75)}$ = 4.51, p<.05, η^2 = .057, and site $F_{(6, 70)}$ = 51.21, p<.001, η^2 = .814. However, these main effects were modified by a two-way interaction of condition × site, $F_{(6, 70)}$ = 4.05, p<.01, η^2 = .26. Decomposition of the condition × site interaction indicated that congruent trials exhibited significantly larger P3b amplitudes than incongruent trials at site POz, t(75) = 4.7, p < .001) and Oz, t(75) = 5.28, p < .001, with no such effects observed at other sites. Examination of the site effect indicated that P3b amplitude achieved its maxima over midline sites in the central and parietal regions which replicated the results of previous research (Polich & Kok, 1995).

Specifically, CPz yielded the largest and clearest P3b amplitudes, so the remainders of the analyses were conducted using P3b recordings from CPz (see Figure 3).

Bivariate, zero-order Pearson product-moment correlations were performed and revealed significant P3b amplitude correlations with SE (r = .31, p < .01; see Figure 4), as well as IQ (r =.33, p < .01). Thus, to assess the relationship between P3b amplitude and SE a hierarchical regression analysis was conducted regressing P3b amplitude on IQ entered as a covariate in the first step, and SE entered in the second step. The overall regression model was significant (R^2 = .16, $F_{(2,73)}$ = 6.9, p = .002) and revealed a significant effect for IQ in the first step as well as a significant effect for SE in the second step, (ΔR^2 = .05, $F_{(1,73)}$ = 4.5, p =.037). This suggests that SE has a unique association with P3b amplitude above and beyond the relation P3b has with IQ, with greater SE associated with larger P3b amplitudes. Table 1 provides a summary of this regression analysis.

P3b latency. The omnibus mixed-model ANOVA revealed two main effects of condition $F_{(1,75)}$ = 48.81, p < .001, η^2 = .39, and site, $F_{(6, 70)}$ = 8.12, p < .001, η^2 = .41. However, these main effects were modified by a two-way interaction of condition × site, $F_{(6, 70)}$ = 7.67, p < .001, η^2 = .40. Decomposition of the condition × site interaction indicated that congruent trials exhibited significantly longer P3b latencies than incongruent trials at sites Cz, $t_{(75)}$ = 8.2, p < .001, CPz, $t_{(75)}$ = 9.3, p < .001, Pz, $t_{(75)}$ = 7.6, p < .001,and POz, $t_{(75)}$ = 3.5, p < .001, with no such effects observed at other sites. Examination of the condition effect demonstrated that, as expected, congruent trials yielded shorter P3b latencies than incongruent trials. Examination of the site effect indicate that P3b latency is longest at the frontal sites and gradually decreases as it moves back over the central and parietal sites (see Figure 3).

P3b and behavior. Bivariate, zero-order Pearson product-moment correlations revealed significant correlations between RT and P3b amplitude, ($r = -.25$, $p < .05$), as well as IQ, ($r = -.32$, $p < .01$), and age, ($r = -.25$, $p < .01$), however no such correlation was present between P3b amplitude and response accuracy, ($r = .10$, $p = .40$; see Figure 5). Thus, to assess the relationship between RT and P3b amplitude, a hierarchical regression analysis was conducted regressing RT on age and IQ entered as covariates in the first step, and P3b amplitude entered in the second step. The overall regression model was significant ($R^2 = .16$, $F_{(3,72)} = 4.44$, $p < .01$) and revealed a significant effect for IQ in the first step of the regression. However, no significant influences were present for age in the first step or P3b amplitude in the second step, ($\Delta R^2 = .03$, $F_{(1,72)} = 2.15$, $p = .15$), of the regression, suggesting that P3b amplitude is not uniquely associated with RT. Table 2 provides a summary of this regression analysis.

Significant correlations were also present between RT and P3b latency, as well as IQ and age. Thus, to assess the relationship between RT and P3b latency, a hierarchical regression analysis was conducted regressing RT on age and IQ entered as covariates in the first step, and P3b latency entered in the second step. The overall regression model was significant ($R^2 = .19$, $F_{(3,72)} = 5.58$, $p < .01$) and revealed a significant effect for IQ, but not age, in the first step of the regressions. Additionally, there was also a significant effect present for P3b latency in the second step, ($\Delta R^2 = .06$, $F_{(1,72)} = 5.14$, $p = .03$), of the regressions, suggesting that P3b latency is uniquely associated with RT. Table 2 provides a summary of this regression analysis.

Self-efficacy Manipulation

Again, all participants were assigned to SE manipulation groups, HE ($n = 24$), LE ($n = 26$), or NE ($n = 26$). A MANOVA examining potential baseline group differences revealed that the P3b latency differed significantly between the three groups on D1, $F_{(2,73)} = 4.4$, $p<.05$, with the LE feedback group (M = 370.9, SD = 56.4) having a significantly shorter P3b latency than the HE feedback (M = 407.3, SD = 48.9) and NE feedback groups (M = 411.8, SD = 56.7). However, no other variable differed significantly between the groups for the first day.

Self-efficacy. To assess changes across task sessions and the effectiveness of the SE manipulation, measures of SE, behavior, and the P3b obtained during D1 were subtracted from those obtained during D2. A significant difference was observed in the change of SE between the three groups, HE (M = 11.8, SD = 11.4), LE (M = -4.7, SD = 11.3), and NE (M = 2.7, SD = 10.9), $F_{(2, 73)} = 13.61$, $p < .01$ (see Figure 6). Independent samples *t*-tests were performed and revealed that the change in SE was significant between the HE feedback group and both the low feedback group, $t_{(46)} = 4.9$, $p < .001$, and the NE feedback group, $t_{(47)} = 2.8$, $p < .01$. There was no significant difference in the change in SE between the LE and NE feedback groups, $t_{(49)} = -2.3$, $p = .024$. This provides evidence that our method for manipulation was successful in modifying SE.

Behavior. There was no significant difference present in the change of overall task accuracy between the HE (M = 3.6, SD = 5.1), LE (M = 5.6, SD = 7.2), and NE (M = 2.0, SD = 11.4) feedback groups, $F_{(2, 73)} = 1.27$, $p = .29$. There was also no significant difference present in the change of RT between the HE (M = -13.9, SD = 24.4), LE (M = -14.2, SD = 23.1) and NE (M = -24.7, SD = 28.1) feedback groups, $F_{(2, 73)} = 1.52$, $p = .23$. This indicates that the manipulation did not have a significant effect on overall task performance.

P3b. There was no significant difference present in the change of P3b amplitude between the HE (M = .95, SD = 3.3), LE (M = 1.2, SD = 2.4) and NE (M = .62, SD = 5.0) feedback groups, $F_{(1, 74)} = .27$, $p = .61$, or the change of P3b latency between the HE (M = -9.2, SD = 46.2), LE (M = -1.1, SD= 37.7) and NE (M = -10.2, SD = 39.6) feedback groups, $F_{(1, 74)} = .28$, *p*

= .60. This indicates that the manipulation did not have a significant effect on stimulus processing.

Additional manipulation correlations. Correlations between change scores and demographics were also performed to assess whether any additional relationships were present after the SE manipulation. A significant relationship was present between IQ and the change in task accuracy, ($r = -.25$, $p < .05$), as well as the change in overall reaction time, ($r = .25$, $p < .05$). There was also a significant relationship present between the change in SE and emotional stability, ($r = .32$, $p < .01$), suggesting that more emotionally stable, or less neurotic, individuals showed greater positive changes in SE across the two task sessions.

Discussion

General Results Observed

Self-efficacy. Consistent with results observed by Bandura (1977), higher SE was found to be associated with improved behavioral measures of task performance. Individuals with higher SE not only displayed increased overall accuracy for the modified flanker task, but also had shorter overall RTs than their lower SE counterparts. This provides additional evidence for the effects of SE on overall task performance and that our SE assessments performed as expected. Further, SE was more strongly correlated with behavioral measures (accuracy, RT) during difficult task conditions (incongruent trials) than during easier task conditions (congruent trials). These relationships are consistent with the social cognitive theory (Bandura, 1986), which states that higher SE will have a more powerful effect on performance when the task difficulty is greater.

After the SE manipulation was performed, the expected changes in SE were observed. Individuals in the HE feedback group were found to have significantly higher (more positive) changes in efficacy than those in the LE and NE feedback group. This provides evidence that our method of manipulation had the desired effect and adequately modified participant SEs for the task. However, it should be noted that there was no significant difference observed between the changes in SE for individuals in the LE or NE feedback groups. It is possible that this may be due to a resiliency, or protective, effect because individuals are less likely to modify their SE in a negative way than in a positive way, and generally attempt to minimize the psychological impact of failure (Wood, Giordano-Beech, Taylor, Michela, & Gaus, 1994). Additionally, it is possible that the effects of the manipulation may be less powerful for those in the LE feedback group due to a possible increase in an individual's confidence in his/her capabilities for the task due to task repetition. This might explain why the LE feedback group did not significantly differ from the NE feedback group in terms of changes in SE.

P3b. The neuroelectric assessment found that the P3b amplitude increased in magnitude from frontal to parietal sites and was largest for central and parietal sites, which agrees with previous literature depicting topographical characteristics of the P3b component (Fabiani et al., 2000; Johnson, 1993; Polich & Kok, 1995; Sutton, 1965). P3b amplitude was also significantly smaller for incongruent task trials, providing support for the increased need for interference control in during the more difficult incongruent tasks (Hillman et al., 2004). As expected, P3b latency was positively associated with RT, and P3b latencies were shorter for the congruent trials, likely due to the lack of time required to detect and evaluate the stimulus and processing demands required for the task (Polich, 2007). Providing converging evidence for the conclusions made by Polich and Martin (1992), a positive relationship was also present between intelligence and P3b amplitude, suggesting that more intelligent individuals have increased stimulus processing abilities. These findings suggest that our equipment and procedures produced the appropriate neuroelectric recordings.

Evaluation of Hypotheses

The first question this study aimed to answer was: Is there a relationship present between SE and stimulus processing? It was hypothesized that since SE has been shown to be related to task performance as well as other neural indices of cognitive processing, than SE would be related to the P3b as well. Specifically, it was predicted that individuals with greater SE would show larger P3b amplitudes during cognitive task completion, suggesting enhanced stimulus evaluation during task execution. Our results supported this hypothesis and indicated that there was, in fact, a significant relationship present between SE and P3b amplitude. This relationship suggests that increased SE was related to enhanced stimulus processing, as evidenced by larger P3b amplitudes, and may even provide evidence that improved stimulus processing may be one mechanism through which SE positively affects overall task performance.

The results also indicate, however, that while there is a relationship between SE and P3b amplitude, there was no such relationship found between P3b amplitude and task performance in this study. This suggests that stimulus processing alone may not be the only cognitive component responsible for the increase in task performance associated with greater SE. Since other cognitive processes related to overall task performance, such as self-regulatory action monitoring (Themanson et al., 2008), have been shown to be affected by SE, it is possible that stimulus processing may just be one of the many components involved in a larger network of processes responsible for the relationship between SE and task performance.

The second question this study aimed to answer was; If SE is modified, is stimulus processing modified as well? It was hypothesized that since SE was found to be related to stimulus processing, then modifications in SE would ultimately lead to modifications in stimulus processing. Specifically, it was predicted that individuals who received HE modifications would not only experience increases in SE, but also in P3b amplitude and individuals who receive LE modifications would experience decreases in both SE and P3b amplitude. Our results indicated that this was not the case. Since there was no significant relationship observed between changes in SE and changes in P3b characteristics. This provides evidence that our specific SE manipulation may not be used as a reliable method for improving stimulus processing.

Additionally, It is important to note that although our results indicated that our SE manipulation was potent enough to significantly modify SE, there was no other significant modification present for any behavioral measure of task performance. Changes in SE were not associated with subsequent changes in task accuracy or reaction time for the task on D2. It is possible that since the manipulations were not powerful enough to influence task performance then they were also not powerful enough to influence stimulus processing. This could be evidence that there is some other factor required for the beneficial effects of SE to be observable. For instance, it is possible that the efficacy manipulation may need to be more integrated, possibly through repeated exposures, so the effect can be more concretely established within the individual before significant effects in behavior or stimulus processing can be observed.

Limitations and Future Directions

The relationship found between SE and stimulus processing is intriguing. However, due to limitations, further investigation is required to develop a more precise theoretical explanation for the significance of this relationship. Because our results indicated that the P3b was not directly related to task performance for our task, it would be important to re-examine the relationship between SE and P3b on a task that is known to show an increase in performance when stimulus processing is increased. If such task is used, the role in which stimulus processing plays in improving task performance can be more properly identified, as well as how SE affects that role.

In order to create a task with a stronger relationship between stimulus processing and task performance, a few modifications must be applied. The task should involve more difficult stimulus processing requirements. If the task requires more difficult stimulus processing for more successful performance, a difference in P3b amplitude might have a greater effect on the task performance. If the task places a greater load on stimulus processing capabilities, then it is possible that SE for that task could have a greater effect on stimulus processing and would provide stronger evidence that stimulus processing may be part of the method by which SE improves task performance. A commonly used example of such task is a task-switching paradigm, where an individual is required to distinguish multiple unrelated stimuli simultaneously in order to be successful (Monsell, 2003). Additionally, the task should be more difficult in general. For the present task, even though deliberate steps were taken to make it difficult, participants still performed very well. This high level of performance may have created a ceiling effect for the task, which did not allow any room for behavioral improvements to be evident during the second task session. Thus, the task should have a higher level of difficulty, which would allow for more variability in performance to be captured and potentially yield significant differences. Moreover, when a task is more difficult, the effect of the feedback on SE may be enhanced. For instance, an individual may be more likely to believe and trust the negative feedback results when the task is difficult enough for poor performance to be perceived as a viable outcome. This may provide additional evidence for why there was no significant difference observed for the change in SE between the LE and NE feedback groups in the present study.

The SE manipulation may also be need to be modified to produce more significant differences in task performance and stimulus processing. Even though our manipulation created significant differences in SE, the lack of changes in task performance suggests that the manipulation may not have been potent enough to produce a fully ingrained, deep-seated modification of SE. It may be that a more extensive SE training program must be utilized over a longer period of time before the manipulation can become better established within the individual (McAuley et al., 1999). Once that change in SE becomes ingrained, then it is possible that a subsequent change in neural and behavioral measures of stimulus processing may be observed.

Summary

In conclusion, SE influences on stimulus processing were examined in healthy young adults. Our results supported previous findings of the influences of internal individual difference variables on the P3b (Brocke, 2004; Gurrera et al., 2001; Polich & Martin, 1992; Stelmack & Houlihan, 1994). Additionally, we found that there is a significant relationship present between SE and P3b amplitude, providing evidence that SE is, in fact, positively related to stimulus processing. This relationship suggests that improved stimulus processing may be, in part, one mechanism through which SE improves task performance. However, simple modifications in SE were not sufficient to significantly improve subsequent stimulus processing and task performance for our chosen task. Although the observed relationship between SE and stimulus processing is intriguing, further exploration is required to explicate the role that SE plays in improving stimulus processing, and how crucial the involvement of stimulus processing is in the relationship SE has with improved task performance.

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Table 1

Summary of Hierarchical Regression Analyses Assessing the Relationship between SE and Accuracy, RT, and P3b Amplitude After Removing the Effects of Relevant Covariates.

Accuracy	B	SE B	Β	P3b Amp.	B	SE B	β

Step 1				**Step 1**			
IQ	.20	.10	.21	IQ	.19	.06	.33*
Step 2				**Step 2**			
IQ	.10	.10	.11	IQ	.15	.06	.26
SE	.14	.04	.36*	SE	.06	.03	-.24*

RT	B	SE B	β
Step 1			
IQ	-1.93	.81	-.27*
Age	-7.93	4.87	-.18
Step 2			
IQ	-1.59	.83	-.22
Age	-7.69	4.83	-1.8
SE	-.52	.34	-.17

Note. RT = reaction time. Amp. = amplitude. * $p < .05$.

Table 2

Summary of Regression Analyses Assessing the Relationship between RT, and P3b Amplitude and Latency After Removing the Effect of Age and IQ.

RT	B	SE B	β

Step 1			
IQ	-1.93	.81	-.27*
Age	-7.93	4.87	-.18
Step 2			
IQ	-1.53	.84	-.21
Age	-8.08	4.83	-.19
P3b Amp.	-2.09	1.43	-.17

RT	B	SE B	β
Step 1			
IQ	-1.93	.81	-.27*
Age	-7.93	.4.87	-.18
Step 2			
IQ	-1.75	.79	-.25*
Age	-6.02	4.81	-.14
P3b Lat.	.22	.01	.25*

Note. Amp. = amplitude. Lat. = latency. * $p < .05$.

Figure Captions

Figure 1. Scatter plot of the relationship between self-efficacy and response accuracy during the first testing session after removing the effect of IQ on each variable.

Figure 2. Scatter plot of the relationship between self-efficacy and reaction time during the first testing session after removing the effects of age and IQ on each variable.

Figure 3. Grand-averaged stimulus-locked waveforms for both task conditions (congruent incongruent) during both testing sessions (D1, D2).

Figure 4. Scatter plot of the relationship between self-efficacy and P3b amplitude (at CPz) during the first testing session after removing the effect of IQ on each variable.

Figure 5. Scatter plot of the relationship between P3b amplitude (at CPz) and response accuracy during the first testing session after removing the effect of IQ on each variable.

Figure 6. Changes in self-efficacy across the testing sessions by feedback groups.

Figure 1

SE and Accuracy

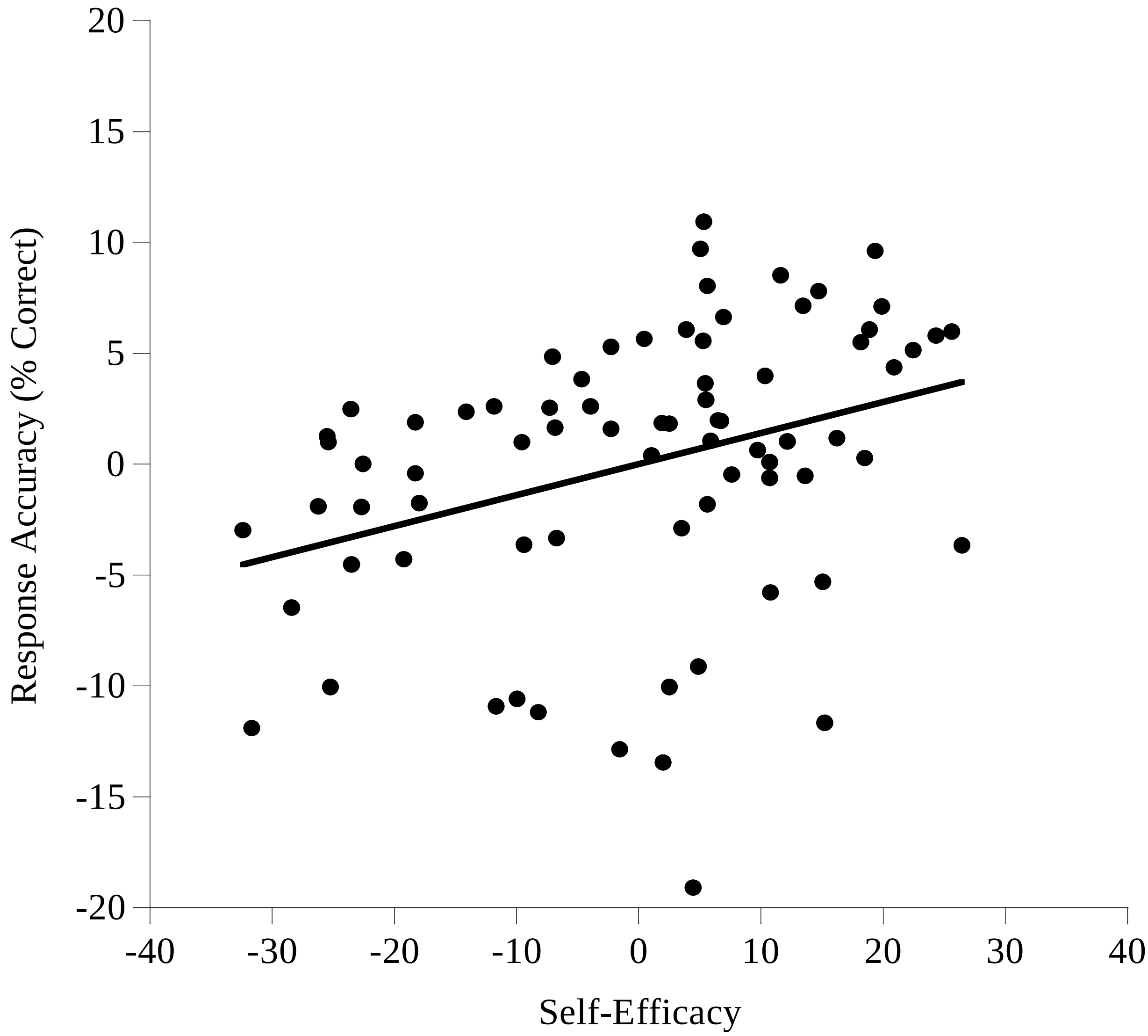


Figure 2

SE and RT

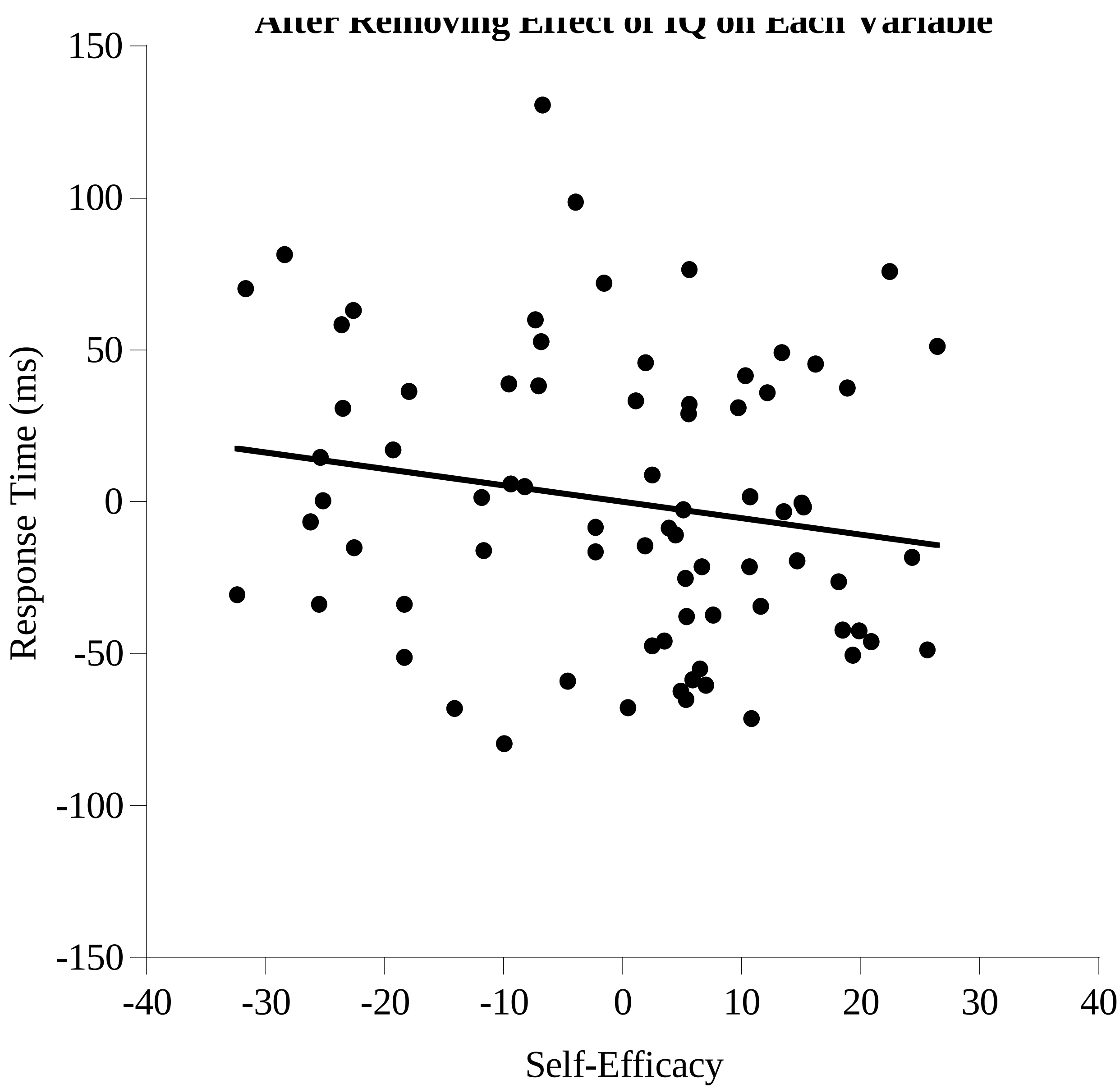

After Removing Effect of IQ on Each Variable
Response Time (ms)
150
100
50
0
-50
-100
-150
-40
-30
-20
-10
0
10
20
30
40
Self-Efficacy

Figure 3

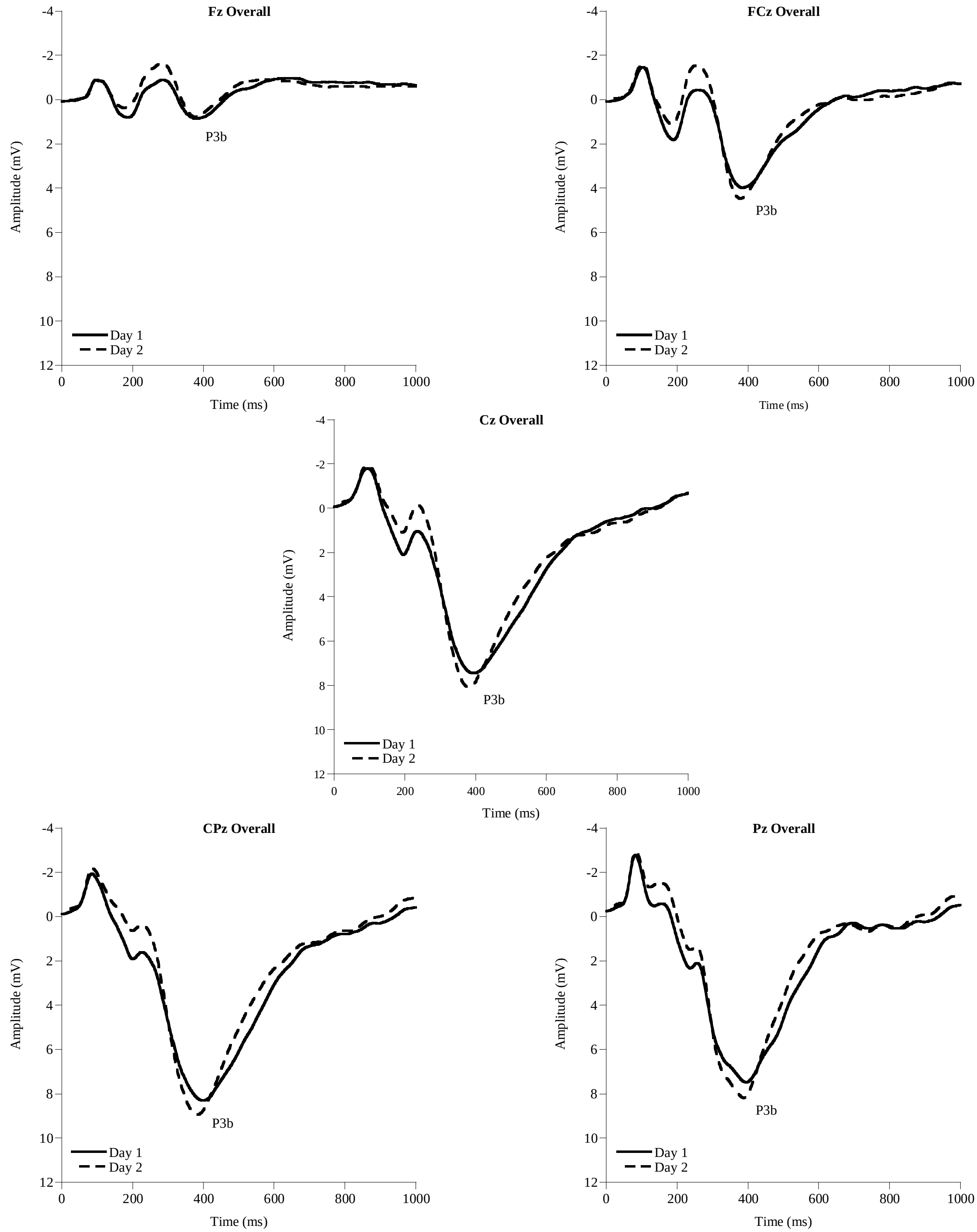

Fz Overall
FCz Overall
Cz Overall
CPz Overall
Pz Overall
P3b
Amplitude (mV)
Time (ms)
Day 1
Day 2
-4
-2
0
2
4
6
8
10
12
0
200
400
600
800
1000

Figure 4

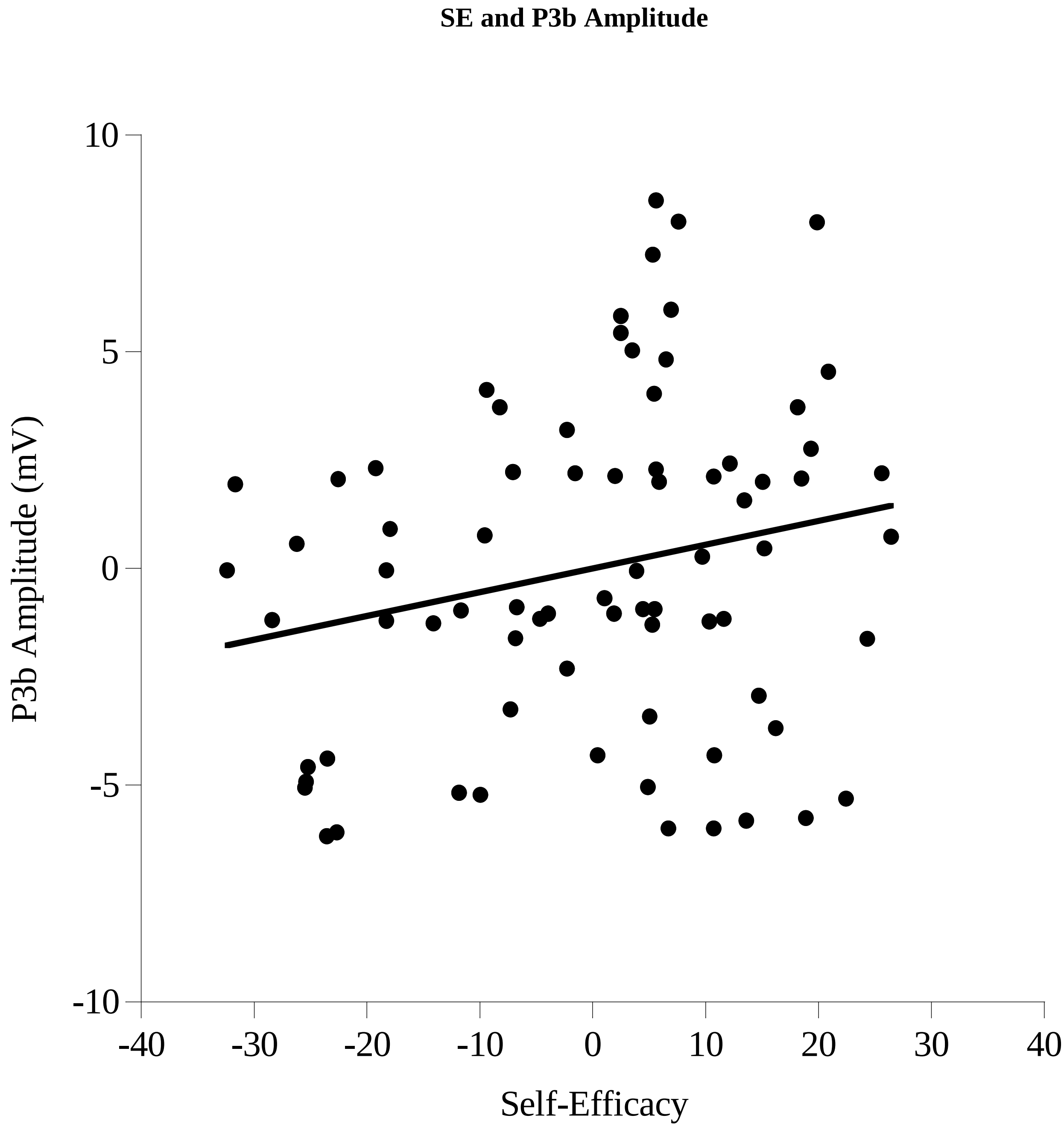

SE and P3b Amplitude
10
5
0
-5
-10
P3b Amplitude (mV)
-40
-30
-20
-10
0
10
20
30
40
Self-Efficacy

Figure 5

P3b Amplitude and Response Accuracy

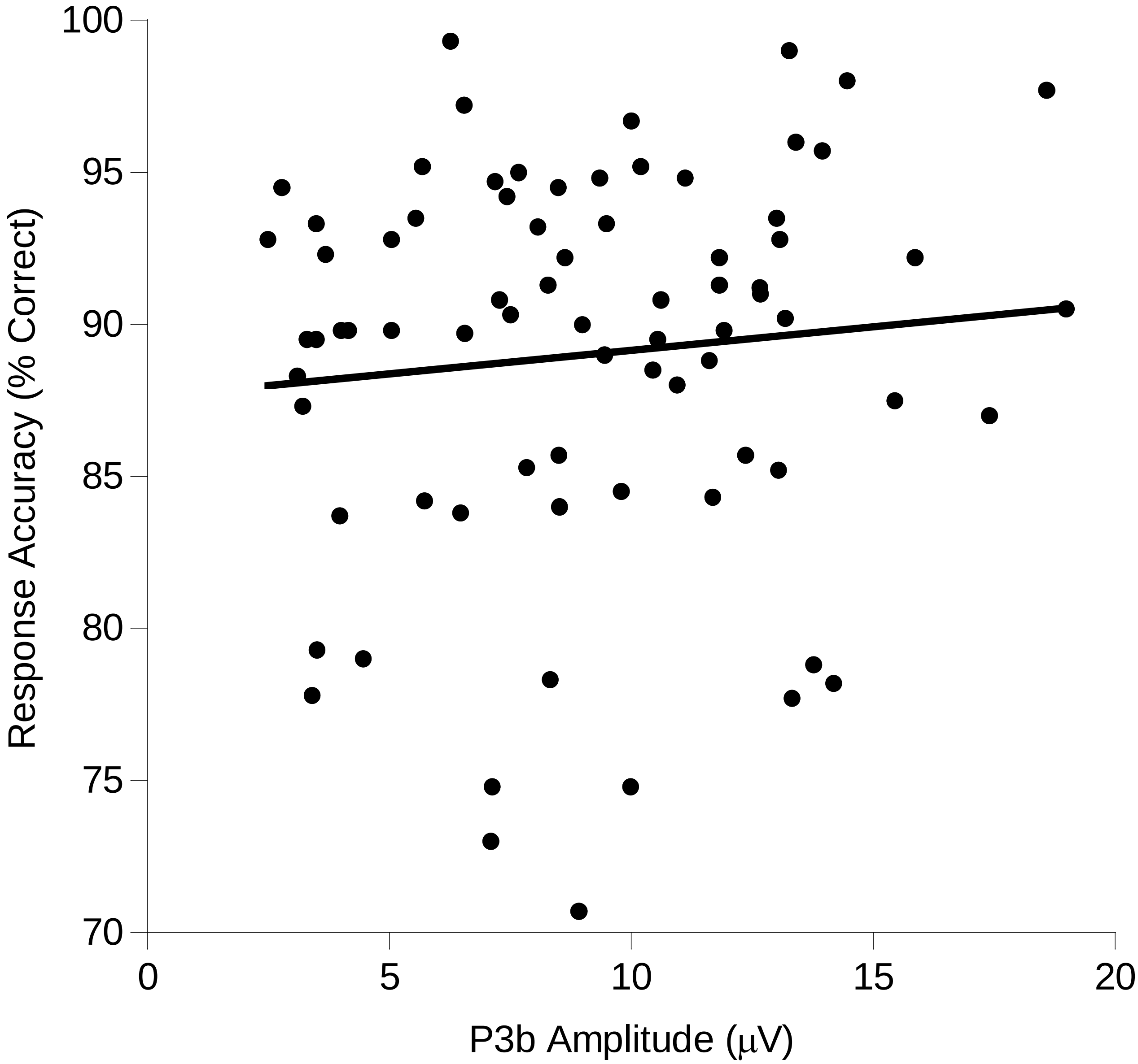
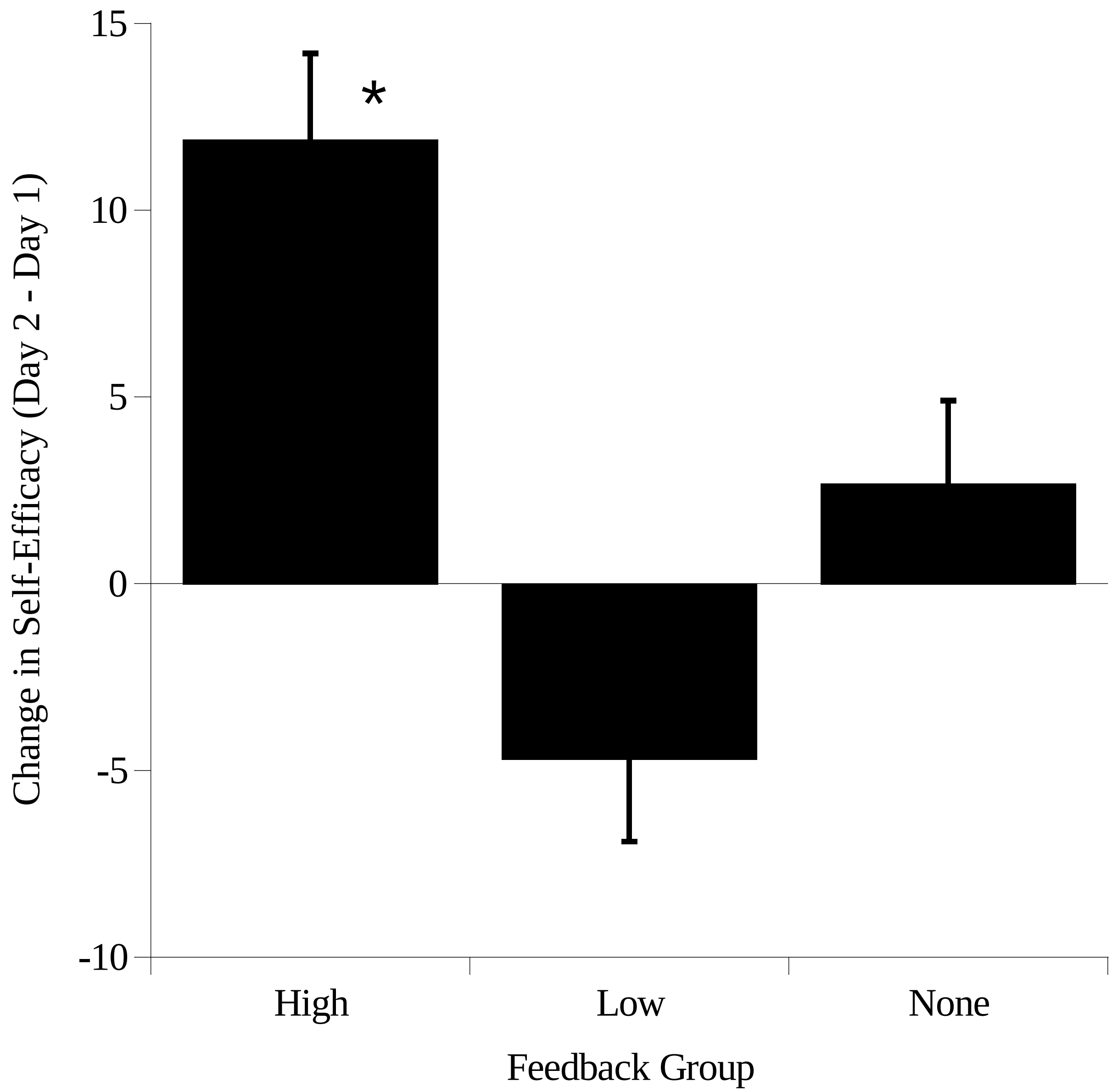


Figure 6

Change in SE


15
10
5
0
-5
-10
Change in Self-Efficacy (Day 2 - Day 1)
*
High
Low
None
Feedback Group