Sensation seeking, the tendency to seek out novel and stimulating experiences despite a high level of risk, is a personality trait that plays a crucial role in dictating human behavior (Zuckerman, 1994). A teenager who prefers lower sensation-seeking activities will likely elect to stay home rather than accompany similarly underage friends to a house party. Conversely, a high sensation seeker will choose to spend time skydiving or bungee jumping, because the adrenaline rush is enjoyable despite the possibility of injury. Many researchers have focused on studying individual differences in sensation seeking, especially when examining the risk-taking behavior often exhibited by individuals who are high sensation seekers. One particular factor of difference is age; researchers have shown that younger adults often have higher sensation-seeking scores than older adults (Roalf, Mitchell, Harbaugh, & Janowsky, 2011; Roth, Schumacher, & Brahler, 2005). It follows, then, that younger adults would also be more likely to partake in high-risk behaviors. This is evidenced by the prevalence of risky behaviors such as drug abuse, crime, and risky sexual behavior seen in younger adults compared to their older adult counterparts (Cowell, Piatel, & Peters, 2019; Turner & McClure, 2003).

**ABSTRACT.** High sensation seeking is associated with increased propensity toward risky behaviors that can be detrimental to oneself and others (Horvath & Zuckerman, 1993). Younger adults not only tend to have higher sensation-seeking scores than older adults, but also demonstrate a greater inclination toward risky behaviors (Cowell, Piatel, & Peters, 2019; Turner & McClure, 2003). The present study considered whether risk-taking behavior is a function of an overactive initiation system (a strong, immediate response to a stimulus) or an underactive inhibitory system (inability to resist an immediate response). With this in mind, the present study examined differences in response initiation and response inhibition among low and high sensation seekers as well as older and younger adults. Participants (18 younger adults and 24 older adults) completed a sensation-seeking questionnaire and Go/No-go task. The results showed differences in inhibition between age groups, controlling for sensation seeking, as measured by the P300 component ($\eta^2 = .22$) and reaction time ($\eta^2 = .24$). In regard to response initiation measured by the late contingent negative variation, the results revealed no differences between age groups or sensation-seeking groups. Any significant findings were exclusive to certain electrode sites, however, so results remain somewhat inconsistent regarding widespread and stable group differences. The present study demonstrates that individual differences, such as age and sensation seeking, may play a role in response initiation and inhibition, underscoring the complexity of the process that leads to risky behavior.

**Keywords:** electroencephalography, sensation seeking, risky behavior, age

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Although high sensation seeking may indeed lead to higher levels of risky behavior, it is also important to consider the roles the initiation system and inhibition system play in risk-taking. Response initiation represents the speed at which people prepare and react to a response to a stimulus, which influences both the way they behave and make decisions (Collins, Corbly, Liu, Kelly, Lynam & Joseph, 2012). It is possible that risk-taking can be explained by an overactive initiation system because a strong initial response to a situation may be too powerful to resist. Individuals who have an abnormally strong impulse to shoplift may engage in that risky behavior because their ordinary ability to refrain from making that response is not sufficient. Response inhibition is another important consideration in behavior management and impulse control, because inhibition allows a person to resist a particular response. Risky behavior may also be due to an underactive inhibition system, because an initial impulse to engage in a risky act cannot be resisted by a weak inhibition system. In response to an urge to shoplift, an individual with an abnormally weak ability to resist that urge may then engage in that risky behavior. In summary, it is unclear whether people engage in greater sensation-seeking activities because they have difficulty refraining from the risky behavior or because they have a strong initial impulse oriented toward that behavior.

One hypothesis was that people make risky decisions because they have an underactive inhibitory system. Yet, some researchers have shown that response inhibition is enhanced in younger adults as compared to older adults (Butler & Zacks, 2006; Kramer, Humphrey, Larish, & Logan, 1994; Schmiedt-Fehr & Basar-Eroglu, 2011). Although these results do not take the sensation-seeking scores of these individuals into account, they do suggest that younger adults of any sensation-seeking level should be able to inhibit responses better than older counterparts of the same sensation-seeking level. This counters the idea that younger adults take risks because of difficulty in inhibition. Another important, although less studied, consideration is response initiation because a high sensation-seeking individual may act rashly due to an overactive initiation system. Although research on this component is sparse, one study did suggest that, in rats, adolescents may be less able to initiate a response than adults (Simon, Gregory, Wood, & Moghaddam, 2013). Again, this finding seems counterintuitive to the fact that younger individuals engage in risky behavior because of an overinvolved initiation system, because they do not initiate a response as quickly as an adult.

Current research on response initiation and response inhibition has yielded conflicting results and made use of drastically different methodologies. Although many studies have focused on variability of response inhibition between individuals of different sensation-seeking levels and age groups (Butler & Zacks 2006; Cowell et al., 2019; Zheng & Liu, 2015), one study suggested that larger individual variability may be found between response initiation, rather than inhibition. Collins, Corbly, Liu, Kelly, Lynam, and Joseph (2012) used functional magnetic resonance imaging (fMRI) to examine brain areas involved in response initiation and response inhibition to uncover any differences that exist between individuals who are low sensation seekers and those who are high sensation seekers. Using a Go/No-Go task to test this hypothesis, the researchers were interested in whether high sensation seekers may engage in risky activities because of an overactive initiation system or an underactive inhibition system. In a Go/No-Go task, participants are asked to initiate a response by pressing a key every time a symbol (e.g., a letter) appears on the screen. These are considered “go” trials. Participants are also asked to inhibit a response by not pressing a key when one particular symbol appears (e.g., the letter X). These are considered “no-go” trials. If high sensation seekers have a weaker inhibitory system, they would have less activation than low sensation seekers in no-go conditions. Conversely, if high sensation seekers have an overactive initiation system, they would have more activation than low sensation seekers in go conditions. The results indicated sensation-seeking group differences in response initiation, not response inhibition. High sensation seeking participants showed greater activation in go conditions than no-go conditions, and this activation lasted longer in high sensation seekers than in low sensation seekers. These findings suggest that high sensation seekers have a more active initiation system than their low sensation-seeker counterparts (Collins et al., 2012).

The present study sought to close some existing gaps in the research by examining both response initiation and response inhibition using behavioral measures and event related potential (ERP) correlates. Many ERP studies do not address
response initiation, and therefore a standard ERP analysis of this process has not been identified. However, the contingent negative variation (CNV) has been used as an indicator of motor preparation and schema activation before a response is carried out and could signal the initiation of a response. The CNV, first described by Grey Walter and colleagues, is elicited by presenting one stimulus that acts as a cue, and then an imperative stimulus that requires a response from the participant. Between these two stimuli, the CNV is present as a slow negative potential (Tecce, 1972; Walter, Cooper, Aldridge, McCallum, & Winter, 1964). The CNV is used to indicate when an individual succeeds in activating the correct schema to respond to an imperative stimulus (Aasen & Brunner, 2016). In a Go/No-Go task, for example, participants will create a cognitive framework that includes the steps leading to a correct response in both go and no-go conditions. Because many more go trials than no-go trials appear throughout the task, the participant will begin to anticipate the need to activate the go schema. By using the CNV to explore when this schema is activated before go trials, it may be possible to track the initiation of each go response. The use of the CNV to indicate the preparation of a motor response has been widely researched and supported (Birbaumer, Elbert, Canavan, & Rockstroh, 1990; Brunia & van Boxtel, 2001; Nagai, Critchley, Featherstone, Fenwick, Trimble, & Dolan, 2004; Rohrbaugh, Syndulko, & Lindsley, 1976; Tecce, 1972). When employing a Go/No-Go task, for example, the CNV may be utilized to identify when participants begin preparing to make a button press, which is the motor response for the go trial they are anticipating. Thus, previous research has demonstrated that the CNV encompasses the first steps of responding to stimuli and therefore can be used as a sign of response initiation because it includes both stimulus processing and motor preparation.

Much more research has been focused on ERP indicators of response inhibition, and has designated the P300 wave as a reliable indicator of motor inhibition (Aasen & Brunner, 2016; Polich, 2007; Sach, Enge, Strobel, & Fleischhauer, 2017; Schmiedt-Fehr & Basar-Eroglu, 2011). In a Go/No-Go task, the P300 peaks about 300–500 ms after the appearance of the letter. Thus, the amount of P300 activation can be used to indicate the effort participants put into inhibiting their go response in each no-go trial (Luck, 2014). Research has shown that both the amplitude and latency of the P300 differ in individuals of different ages. The P300 shows a larger amplitude and shorter latency in young adults, whereas older adults show a smaller amplitude and increased latency of this component (Dully, McGovern, & O’Connell, 2018; Polich, 2007; Schmiedt-Fehr & Basar-Eroglu, 2011).

Age differences in an ERP component used to indicate inhibition may hint at overall differences in inhibition abilities in individuals as they age. Behavioral traits have also been shown to affect the P300, although presently the literature in this area is sparse. For example, low-arousal individuals, who will likely also be low in sensation seeking, tend to show smaller P300 amplitudes than those who are high-arousal (Polich, 2007).

The present study used the CNV and P300 ERP components as well as behavioral analyses of participants’ performance on a Go/No-Go task to examine differences in response initiation and response inhibition among low sensation seekers and high sensation seekers. It also examined how response inhibition and initiation may differ between younger adults and older adults. Low sensation seekers were compared with high sensation seekers to examine differences in response initiation and inhibition abilities. If high sensation seekers had an overactive initiation system, then we expected the CNV to show large differences between low and high sensation seekers. Conversely, if high sensation seekers possessed an underactive inhibitory system, then we expected them to exhibit a larger P300 waveform on No-Go trials compared to the low sensation seekers. Any differences in response inhibition between sensation-seeking group or age group would also be indicated by differences in reaction time when responding to the Go/No-Go task. Previous research has demonstrated that older adults typically have slower reaction times (Fozard, Vercruysse, Reynolds, Hancock, & Quilter, 1994). Older adults and younger adults were also compared on sensation-seeking scores and ERP components indicating initiation and inhibition. Based on previous literature, older adults were expected to have lower sensation-seeking scores than younger adults (Roalf et al., 2011; Roth et al., 2005). Additionally, younger adults have previously demonstrated a larger P300 amplitude and shorter latency than older adults, which may indicate that older adults struggle more with inhibition (Dully et al., 2018; Polich, 2007; Schmiedt-Fehr & Basar-Eroglu, 2011).
Rooted in the findings of previous research, we developed three exploratory hypotheses: (a) older adults would have lower sensation-seeking scores than younger adults; (b) ability to inhibit, as indicated by P300 and reaction time, would differ by age group (older vs. younger) and sensation-seeking group (low vs. high); and (c) ability to initiate a response, as indicated by the late CNV, would differ by age group (older vs. younger) and sensation-seeking group (low vs. high).

**Method**

**Participants**

Participants were a convenience sample consisting of 24 older adults ($M = 71.83$ years; $SD = 8.54$ years; range = 57–87 years; 54.20% women) and 18 younger adults ($M = 20.28$ years, $SD = 1.02$ years, range = 19–22 years; 38.90% women). Older adults were recruited through word of mouth, a local community center, church bulletins, and community flyers. The older adult participants were recruited from an upper Midwestern town located in the United States. Among residents of this town, 77.40% identified as White (U.S. Census Bureau, 2017). The younger adult participants were recruited from a small, private, four-year, primarily undergraduate, highly residential college located in the same town. The undergraduate student population from which younger adult participants were drawn most frequently identified as European American (87%). Many of the younger adults were recruited through an online participant pool and took part in the study in exchange for course credit. Participants in the present investigation were part of a larger study examining the influence of personality and early life experiences on risky decision making in younger and older adults.

**Measure and Procedure**

First, approval from the St. Norbert College institutional review board was obtained (FWA #14-02-006) for the study entitled Decision Making in an ERP Environment. At the beginning of each experimental session, participants were greeted and then completed an informed consent form, a demographics questionnaire (e.g., age, sex, employment status, living arrangements, marital status, level of education), the Sensation-Seeking Scale, and other measures beyond the scope of these analyses. Next, we asked participants to take a seat in a testing room with a computer. Then, the electroencephalogram (EEG) system was set up for data collection. We placed the 32-electrode cap on each participant’s head and inserted a small amount of conductive gel into each channel to allow for a clear signal. Subsequently, participants completed a resting state task and three other computerized tasks. Only the Go/No-Go task was used for the present study.

**Sensation-Seeking Scale**

We measured sensation-seeking level with the impulsive-sensation seeking section of Zuckerman’s (1994) Zuckerman–Kulhman Personality Questionnaire (ZKPQ). The Sensation Seeking Scale was a 13-item, forced-choice, self-report inventory that measured overall sensation seeking, as well as four subscales (thrill and adventure seeking, disinhibition, experience seeking, boredom susceptibility). For each item, one statement was consistent with high sensation seeking and the other was consistent with low sensation seeking. Participants selected the statement (A or B) that they believed best described them. Each high sensation seeker response was coded as 1 and each low sensation-seeking response was coded as 0. Thus, scores could range from 0 to 13. Zuckerman demonstrated that the ZKPQ had high internal consistency for women (.81) and men (.77).

**EEG Recording**

We collected EEG data using a 32-electrode acti-CHamp system. The system was set at 2kHz and used the O1 and O2 electrodes as references. We set all 32 electrode impedances below 30 KOhms. We then conducted analyses of the electrophysiological data using Brain Vision Analyzer software. We downsampled the data offline from 512 Hz to 256 Hz. After referencing these data to an average of all electrodes, we used an IIR filter of 0.1-30 Hz along with a notch filter of 60 Hz. Using a 2200 mV to 200 mV threshold, we completed artifact rejection. Additionally, we visually inspected and removed bad channels. To identify and correct ocular movements, we used Gratton-Coles ocular artifact correction, seeded off of electrode Fp1. After the preprocessing procedures, we separated the data by stimulus type (i.e., go, no-go). We created Epochs with 200 ms baselines and 1000 ms stimulus presentation following the onset of each go or no-go trial. Next, each epoch was averaged, depending on stimulus type, and baseline corrected. We combined the corrected averages for each participant to calculate a grand average, allowing them to analyze the ERP component for each participant based on trial type. From these
data, we examined two ERP waveforms: the late CNV on all go trials (100 ms prestimulus of the following trial), and the P300 on correct no-go trials (300–600 ms poststimulus of current trial). Finally, we extracted the mean amplitude for the late CNV from the Pz, Fz, and Cz electrodes, and the mean amplitude for the P300 from the P3, P4, C3, C4, F3, and F4 electrodes.

Resting State
After the EEG equipment was in place, each participant completed two 4-minute resting state measures. For the first resting state measure, each participant was instructed to sit completely still with eyes open. For the second resting state measure, participants completed a similar process of remaining still, but this time with eyes closed for 4 minutes.

Go/No-Go Task
Each participant completed the Go/No-Go Task (Luria, 1961). In this task, participants watched as a series of letters appeared on a computer monitor. We instructed participants to respond when a go stimulus appeared and to refrain from responding when the no-go stimulus appeared. We told participants to initiate a response by pressing the spacebar each time they saw a letter (go stimulus), except if the letter was X (no-go stimulus). The task included 150 go trials and 50 no-go trials. Therefore, the number of correct responses for each participant could have ranged from 0 to 200. During each trial, participants saw a capital letter appear on the screen for 1000 ms. The interstimulus interval was jittered between 500 and 1000 ms, during which participants saw a fixation crosshair in the middle of the screen. Inhibition of a response occurred when the participant correctly refrained from responding to a no-go trial. Initiation of a response occurred when the participant correctly responded on a go trial. EEG data (P300 and CNV) was collected during this task, as well as data concerning the participant’s reaction time for each trial.

Results
Sensation-Seeking Scores
The first hypothesis was that older adults would have lower sensation-seeking scores than younger adults. Using a median split of total sensation-seeking scores, we divided participants into a low and high sensation-seeking group. We placed all participants with a total sensation-seeking score of 6 to 13 in the high sensation-seeking group. We used a median split to create two nearly equal sensation-seeking groups for experimental comparison. These same groups were then used in subsequent analyses. Ultimately, the sample consisted of 22 low sensation seekers (M = 4.00, SD = 0.93, range = 2–5; 50% women) and 20 high sensation seekers (M = 7.95, SD = 1.32, range = 6–10; 45% women).

We conducted a chi-square test to examine the relationship between age category (older vs. younger) and sensation-seeking group (low vs. high). The relation between these variables was significant, χ²(1, N = 42) = 4.58, p = .03. Older adults were more likely to be in the low sensation-seeking category than were younger adults, whereas younger adults were more likely to be in the high sensation-seeking category (see Figure 1). As a measure of effect size, we calculated a Cramer’s V of .33, indicating a strong association between age category and sensation-seeking score.

Ability to Inhibit a Response
The second hypothesis was that ability to inhibit, as indicated by P300 and reaction time, would differ by age group (older vs. younger) and sensation-seeking group (low vs. high). We verified that the assumptions for the Analysis of Variance (ANOVA) were met before proceeding with the following analyses. To assess potential P300 waveform differences on no-go trials, we conducted a 2 (age group) x 2 (sensation-seeking group) ANOVA, combining results from all electrodes to explore differences between each participant’s average P300. We did not find any significant differences, F(3, 38) = 1.62, p = .20. Initially, we included all 32 electrodes included in the ANOVA. In an effort to reduce noise, we conducted additional analyses on the specific electrodes of interest for the P300 component previously identified in the literature (i.e., F3, F4, P3, P4, C3, and C4; Picton, 1992).
Figure 2. Mean P300 amplitudes are shown for older and younger adults at the frontal electrodes F3 (top panel) and F4 (bottom panel).
To assess differences in the P300 on no-go trials at the frontal electrodes (i.e., F3, F4), a 2 (age group) by 2 (sensation-seeking group) ANOVA was conducted. There were no statistically significant interactions. There was a significant main effect of age group, $F(1, 38) = 9.65, p = .004$. This result indicated that older adults had more activation than younger adults (2.80 ± 4.40 vs. -0.02 ± 1.58, respectively). This relationship had a moderate effect size, $\eta^2 = 0.20$ (see Figure 2).

To assess differences in the P300 on no-go trials at the parietal electrodes (i.e., P3, P4), a 2 (age group) by 2 (sensation-seeking group) ANOVA was conducted. There were no statistically significant interactions. There was a significant main effect of age group, $F(1, 38) = 11.69, p = .002$. These results indicated that younger adults had more activation than older adults (2.64 ± 1.97 vs. 0.77 ± 2.15, respectively). This relationship had a moderate effect size, $\eta^2 = 0.22$. The results also showed a significant difference between older adults (M = 0.64) and younger adults (M = 2.81) in the P300 component on no-go trials at the parietal electrodes (i.e., P3, P4), $F(1, 39) = 10.99, p = .002$ (see Figure 2). This relationship also had a moderate effect size, $\eta^2 = 0.22$.

To assess potential differences in reaction time, we conducted a 2 (age group) x 2 (sensation-seeking group) ANOVA. No statistically significant interactions were found. There was a significant main effect of age group, $F(1, 36) = 11.21, p = .002$. According to this result, older adults had significantly slower reaction times than their younger adult counterparts (555.73 ± 100.29 vs. 452.48 ± 61.87, respectively). Age group had a moderate effect on reaction time, $\eta^2 = 0.24$. The high variability in reaction times as seen by the large standard deviations could be a possible reason the investigators did not find other significant differences.

### Ability to Initiate a Response

The third hypothesis was that ability to initiate a response, as indicated by the late CNV, would differ by age group (older vs. younger) and sensation-seeking group (low vs. high). We verified that the data met assumptions for ANOVA before proceeding with the following analysis. To assess potential differences in the CNV on go trials, we conducted a 2 (age group) x 2 (sensation-seeking group) ANOVA, combining results from all electrodes to explore differences between each participant’s average CNV. The results indicated no statistically significant interactions as well as no significant differences in the CNV between age group or sensation-seeking group. After conducting an ANOVA using all 32 electrodes, we utilized previous research to identify specific electrodes that were of particular interest for the CNV (i.e., Pz, Cz, and Fz; Aasen & Brunner, 2016). To assess potential differences in the CNV on go trials at the Pz, Cz, and Fz electrodes, we conducted three separate 2 (age group) by 2 (sensation-seeking group) ANOVA, one for each electrode. There were no statistically significant interactions. The results demonstrated no significant differences between sensation-seeking groups at the Pz, Cz or Fz electrode. In addition, the results demonstrated no significant differences in the CNV between older adults and younger adults in either the Pz, Fz, or Cz electrode.

A one-way ANCOVA, controlling for total SS score, revealed a significant difference between older adults (M = 2.88) and younger adults (M = 0.12) in the P300 component on no-go trials, at the frontal electrodes (i.e., F3, F4), $F(1, 39) = 11.09, p = .002$. This relationship had a moderate effect size, $\eta^2 = 0.22$. The results also showed a significant difference between older adults (M = 0.64) and younger adults (M = 2.81) in the P300 component on no-go trials at the parietal electrodes (i.e., P3, P4), $F(1, 39) = 10.99, p = .002$ (see Figure 2). This relationship also had a moderate effect size, $\eta^2 = 0.22$.

Because of the relationship between age group and sensation-seeking score established in Hypothesis 1 (younger adults: 6 low sensation seekers, 12 high sensation seekers; older adults: 16 low sensation seekers, 8 high sensation seekers), we conducted additional tests, controlling for both age and sensation-seeking group in separate analyses, to determine whether this relationship was masking possible differences in the P300 component. Before performing Analyses of Covariance (ANCOVAs) for the frontal electrodes (i.e., F3, F4) or the parietal electrodes (i.e., P3, P4), we verified that the basic assumptions were met. We did not conduct an ANCOVA for the central electrodes (i.e., C3, C4) because these data did not meet the basic assumptions of homogeneity of regression slopes for ANCOVA.

A one-way ANCOVA, controlling for age, revealed no significant differences between low and high sensation seekers in the P300 component on no-go trials at the frontal electrodes (i.e., F3, F4), $F(1, 39) = 0.01, p = .91$, or the parietal electrodes (i.e., P3, P4), $F(1, 39) = 3.09, p = .09$. To assess differences in the P300 on no-go trials at the central electrodes (i.e., C3, C4), a 2 (age group) by 2 (sensation-seeking group) ANOVA was conducted. There were no statistically significant interactions. There was a significant main effect of age group, $F(1, 39) = 3.09, p = .09$. There was not a significant main effect of sensation-seeking group, $F(1, 38) = 1.31, p = .26$.

### A one-way ANCOVA, controlling for total SS score, revealed a significant difference between older adults (M = 2.88) and younger adults (M = 0.12) in the P300 component on no-go trials, at the frontal electrodes (i.e., F3, F4), $F(1, 39) = 11.09, p = .002$. This relationship had a moderate effect size, $\eta^2 = 0.22$. The results also showed a significant difference between older adults (M = 0.64) and younger adults (M = 2.81) in the P300 component on no-go trials at the parietal electrodes (i.e., P3, P4), $F(1, 39) = 10.99, p = .002$ (see Figure 2). This relationship also had a moderate effect size, $\eta^2 = 0.22$. To assess potential differences in reaction time, we conducted a 2 (age group) x 2 (sensation-seeking group) ANOVA. No statistically significant interactions were found. There was a significant main effect of age group, $F(1, 36) = 11.21, p = .002$. According to this result, older adults had significantly slower reaction times than their younger adult counterparts (555.73 ± 100.29 vs. 452.48 ± 61.87, respectively). Age group had a moderate effect on reaction time, $\eta^2 = 0.24$. The high variability in reaction times as seen by the large standard deviations could be a possible reason the investigators did not find other significant differences.

### Ability to Initiate a Response

The third hypothesis was that ability to initiate a response, as indicated by the late CNV, would differ by age group (older vs. younger) and sensation-seeking group (low vs. high). We verified that the data met assumptions for ANOVA before proceeding with the following analysis. To assess potential differences in the CNV on go trials, we conducted a 2 (age group) x 2 (sensation-seeking group) ANOVA, combining results from all electrodes to explore differences between each participant’s average CNV. The results indicated no statistically significant interactions as well as no significant differences in the CNV between age group or sensation-seeking group. After conducting an ANOVA using all 32 electrodes, we utilized previous research to identify specific electrodes that were of particular interest for the CNV (i.e., Pz, Cz, and Fz; Aasen & Brunner, 2016). To assess potential differences in the CNV on go trials at the Pz, Cz, and Fz electrodes, we conducted three separate 2 (age group) by 2 (sensation-seeking group) ANOVA, one for each electrode. There were no statistically significant interactions. The results demonstrated no significant differences between sensation-seeking groups at the Pz, Cz or Fz electrode. In addition, the results demonstrated no significant differences in the CNV between older adults and younger adults in either the Pz, Fz, or Cz electrode.
Figure 3. Mean P300 amplitudes are shown for older and younger adults at the parietal electrodes P3 (top panel) and P4 (bottom panel).
Again, we conducted additional analyses controlling for both age group and sensation-seeking score because of the previously determined relationship between the two variables (younger adults: 6 low sensation seekers, 12 high sensation seekers; older adults: 16 low sensation seekers, 8 high sensation seekers). These analyses helped determine possible differences in the CNV that were obscured by the association between age and sensation-seeking group. Before conducting these analyses, we ensured that the data met all basic assumptions for ANCOVA. A one-way ANCOVA, controlling for age, revealed no significant differences between low sensation seekers and high sensation seekers in the CNV on go trials at the Pz electrode, $F(1, 38) = 3.79, p = .06$, the Fz electrode, $F(1, 39) = 0.78, p = .38$, or the Cz electrode, $F(1, 39) = 0.27, p = .61$.

A one-way ANCOVA, controlling for total SS score, revealed no significant differences between older adults and younger adults in the CNV on go trials at the Pz electrode, $F(1, 38) = 0.18, p = .68$, the Fz electrode, $F(1, 39) = 0.26, p = .62$, or the Cz electrode, $F(1, 39) = 0.24, p = .63$.

**Discussion**

The purpose of the present study was to investigate two possible explanations for engagement in risky behavior: an overactive initiation system and an underactive inhibitory system. Further, we sought to determine how individual differences such as sensation-seeking level and age could influence response initiation and inhibition. We also aimed to discover potential differences in sensation-seeking levels between younger and older adults.

**Sensation-Seeking Scores**

Based on previous research, we hypothesized that older adults would have lower sensation-seeking scores than younger adults (Roalf et al., 2011; Roth et al., 2005). Consistent with this hypothesis, older adults did have lower sensation-seeking scores than younger adults. This suggests that individual differences in sensation-seeking may be partially attributable to age. Moreover, because older adults are less likely to be high sensation seekers, they are also less likely to engage in risky behaviors, compared to their younger adult counterparts. Based on this premise, older adults are unlikely to seek out risky behaviors such as speeding or gambling. It is possible that less risk is necessary for older adults to achieve optimal arousal levels, so additional novel sensations are unnecessary.

**Ability to Inhibit a Response**

For our second hypothesis, we expected ability to inhibit, as indicated by P300, and reaction time to differ by age (older vs. younger) and sensation-seeking group (low vs. high). The ability to inhibit—examined in this study via the P300 component and reaction time—is an essential component to understanding an individual’s impulse control and decision making. If a specific group of individuals struggle to inhibit their responses, they may engage in high-risk behaviors because of an inability to quell their initial desire to participate in the activity. This is one possible explanation for why individuals who are high in sensation seeking often make more risky decisions than their low sensation-seeking counterparts. Additionally, research has shown differences in response inhibition between older and younger adults (Butler & Zacks, 2006; Schmiedt-Fehr & Basar-Eroglu, 2011). To explore both of these possibilities, we examined possible age and sensation-seeking differences in both the P300 component and reaction time.

In previous research, differences in the P300 component have been cited between both age and sensation seeking group. In general, the P300 component has been found to increase in latency with increasing age (Dully et al., 2018; Falkenstein, Hoormann, & Hohnsbein, 2002; Polich, 1997) and decrease in amplitude (Dully et al., 2018; Schmiedt-Fehr & Basar-Eroglu, 2011). Sensation seeking has also been implicated in differences in the P300. Specifically, Zheng and Liu (2015) found that, when responding to a gain or loss, higher sensation seekers tended to have lower P300 amplitudes.

When examining the P300 component using both age and sensation seeking, the current study found differences only between age groups, not sensation-seeking groups. Even when we controlled for these observed age differences and only explored the effect of sensation seeking, results still indicate a lack of differences between individuals who are low and high sensation seeking regardless of their age. Thus, the current study differs from those previously conducted in that, when utilizing the P300 component as an indicator, inhibition did not appear to differ between those of different sensation-seeking levels. Based on differences in the P300 component, however, older and younger adults did appear to differ from each other in inhibition abilities. Results revealed clear age group differences in the P300 at both frontal and parietal electrodes, which remained significant even after controlling for any possible variance due to differing sensation-seeking scores. The direction...
of this relationship is unclear, however, because older adults had significantly more P300 activation than younger adults at the frontal (i.e., F3, F4) electrodes, but significantly less at the parietal (i.e., P3, P4) electrodes. Although previous research has suggested that younger adults should have better inhibitory abilities than older adults (Butler & Zacks, 2006; Schmiedt-Fehr & Basar-Eroglu, 2011), this relationship was not clear in the present investigation. It is possible that younger and older adults were approaching the Go/No-Go task using different neural networks, as indicated by older adults having more activation in the frontal lobe but less activation in the parietal lobe compared to their younger adult counterparts. Previous research (Schmiedt-Fehr & Basar-Eroglu, 2011) has demonstrated that older adults use compensatory activation to enlist other brain areas not usually activated during the task to assist them in completing it. Thus, older adults might have been activating frontal brain areas that younger adults did not need to activate in order to effectively inhibit a response. Future research would benefit from employing an imaging method with more spatial resolution, such as fMRI. This would allow investigators the ability to tease apart which areas of the brain are specifically activated in each age group.

The examination of reaction time revealed differences that exist between age groups, but not sensation-seeking groups. Results showed that older adults have significantly slower reaction times than younger adults. Considering previous research on age and reaction time (Fozard et al., 1994), the finding that older adults react slower is not surprising. Based on this finding, inhibition seems to be more difficult in older adults, and therefore takes more time. During no-go trials throughout the task, participants become used to inhibiting the go response in order to refrain from pressing the button on each no-go trial. Older adults need to expend more effort to engage in this response inhibition, but during go trials, they are required to override this inhibition in order to make the correct response. Our results indicate that this process takes more time for older adults, suggesting that it is more difficult for them.

Our findings suggest that inhibition does seem to differ between those of different age groups but not sensation-seeking groups, although specific conclusions are difficult to draw. It is possible that, with more participants, the relationship between one’s age or sensation-seeking level and the inhibition of responses would have been more clear.

**Ability to Initiate a Response**

The third hypothesis was that ability to initiate a response, as indicated by the late CNV, would differ by age (older vs. younger) and sensation-seeking group (low vs. high). Individuals’ response initiation, or how quickly they begin to react, also plays a large role in their behaviors and decisions. Someone who has a very strong initial response to a situation, regardless of the amount of risk, will be more likely to act on it. Some have argued that high sensation seekers engage in risky behaviors for this reason, because their original desire for something overpowers everything else (Collins et al., 2012). Our goal was to consider this possibility, as well as potential age and sensation-seeking differences in initiation ability.

An examination of the late CNV component demonstrated no differences between low and high sensation seekers. This suggests that all individuals, regardless of sensation-seeking level, should have a similar ability to initiate a response. This finding conflicts with previous research conducted by Collins et al. (2012), which indicated that high sensation seekers exhibited more activation and therefore were able to initiate a response more readily. These inconsistent results may indicate that other individual differences not explicitly measured in these studies are leading to observed differences or similarities in initiation ability. Perhaps a specific facet of sensation seeking, or another variable entirely, plays a larger role in determining an individual’s ability to initiate a response. The initiation of responses by sensation-seeking level has not been widely studied, so more research is needed to clarify these conflicting results and reach a more sound conclusion.

Based on research conducted by Simon et al. (2013), we also expected possible differences in initiation between older and younger adults, but did not find results to support this. There were no differences in the initiation of responses between older and younger adults as measured by the CNV, which is inconsistent with the findings of Simon et al.’s study. This study, although conducted on rats, demonstrated age differences in the initiation of responses, particularly that younger rats had a more difficult time with initiation. More research on the initiation systems of human subjects is necessary to draw a firm conclusion as to how initiation of responses may change as we age.
Limitations and Future Research
The present study presents several limitations and recommendations for future research. First, although the sample size was sufficient to examine participants by age or sensation-seeking group—as indicated by the samples used in similar previous research which split participants into two groups (Zheng & Liu, 2015; Schmiedt-Fehr & Basar-Eroglu, 2011)—a power analysis revealed that a larger sample (i.e., 45 per group) would have been ideal when participants were split into four Age x Sensation-Seeking groups. Thus, this sample did not allow for the statistical power necessary to detect all of the potential differences we were interested in investigating. Future studies should thus recruit a larger sample to effectively study these differences.

Additionally, the present study did not collect all relevant participant characteristics such as race and ethnicity. Thus, it cannot be determined if participant race or ethnicity was related to the initiation or inhibition of a response on the Go/No-Go task. Future investigations should collect all potentially relevant participant characteristics to best capture individual differences that occur in the inhibition and initiation of responses.

By examining both older and younger adults in this study, we were able to explore possible age differences in both initiation and inhibition between these two groups. Because these two groups are so disparate, however, there was no way to track the pathway of changes that occurs as participants age. Future research may benefit from including participants in middle adulthood as well to examine the direction of these changes more closely. Another age-related limitation might have been that younger adults often feel more comfortable with using technology. As a result, they might have performed the computer tasks with greater ease and felt more comfortable with the EEG system.

Further, although EEG methodology is a helpful tool, it does not allow for the precision necessary for localization of specific neural structures that may be differentially impacted as individuals of different sensation-seeking levels grow older and make risky decisions. In the current study, for example, activation at frontal and parietal electrodes differed between age groups when inhibiting responses. Because of the inability to localize these responses, however, it is unclear exactly which brain regions were utilized by members of each age group. Future research may benefit from a more precise methodology, such as using fMRI.

The present study found differences in response inhibition, but results did not indicate any complementary differences in response initiation. Very little previous research has examined both systems in the same group of individuals. Future research on risky decision making should continue to explore initiation, not just inhibition, to clarify and augment the findings in this study. Further, the current study used the CNV as an indicator of initiation. However, because initiation has not been widely studied in humans, more research is needed to determine if the CNV is the singular best component to study initiation. In future studies, participants could be asked to complete several types of cognitive tasks which require response initiation, such as oddball tasks, in order to explore ERP components that are consistently activated during these tasks. Perhaps the CNV in conjunction with other ERP components provides even a better indicator of the response initiation process. Lastly, the use of the Go/No-Go task in the present investigation allowed for examination of the processes of response initiation and inhibition, but future research is needed to more confidently translate these findings to risky decision making. This version of the Go/No-Go task had little to no risk attached because participants did not gain or lose points, nor were they rewarded for their performance. When completing a task that incorporates more risk, the cognitive processes of initiation and inhibition may be altered, and differences between age and sensation-seeking group may become more or less prominent. In future research, these cognitive processes should be examined using a risky task in order to more clearly understand how differences in response initiation and inhibition can be linked to risky decision making.

Conclusion
The purpose of this exploratory study was to add to what is known about how differences in response initiation and response inhibition may contribute to risk-taking behavior, and how this relationship could be affected by age and sensation-seeking score. The results revealed that older adults are lower in sensation-seeking level compared to younger adults. Additionally, age differences were detected in the ability to inhibit a response, although it is unclear which age group has the most difficulty with inhibition. Results indicated no differences in response inhibition between those of different sensation-seeking levels, as well as no differences in initiation based on either age...
or sensation-seeking group. An absence of clear and consistent group differences in initiation and inhibition makes it difficult to draw possible conclusions about which groups may possess either an overactive initiation system or an underactive inhibitory system. As this study has shown, the process that leads individuals to engage in risky behavior involves several factors, including aspects of age and other possible individual differences not yet identified. This process is extremely complex and requires continued research to be more accurately understood.

References

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