The Role of Inner Speech in Modulating Electrophysiological Stress Responses

İçsel Konuşma Sıklığına Göre Bilişsel ve Fizyolojik Stres Tepkilerinin Karşılaştırılması

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ABSTRACT

The frequency and reliance on inner speech (IS) vary across individuals and may influence self-regulation processes such as emotion regulation and impulse control. This study examined whether IS frequency is associated with differences in emotion regulation, impulsive behavior, and physiological stress responses. The sample consisted of 35 university students aged 18–39.

IS frequency was treated as a continuous predictor. Associations between IS frequency, self-report measures of emotion regulation and impulsivity, task performance (Stroop task), and physiological responses (heart rate (HR) and skin conductance level (SCL)) were analyzed using correlation, linear regression, and repeated-measures ANOVA. Results showed no significant associations between IS frequency and emotion regulation, impulsivity, Stroop task accuracy, or reaction times. A significant main effect of task condition on SCL was observed, with mental arithmetic eliciting higher electrodermal activity than baseline and Stroop conditions, confirming successful stress induction. However, regression analyses revealed no relationship between IS frequency and physiological responses across tasks. The only significant finding emerged at baseline: higher IS frequency predicted lower resting HR ($\beta = -.48$, $p = .004$, $R^2 = .23$). Overall, IS frequency did not substantially influence cognitive or physiological outcomes. Future research should use larger samples, counterbalanced designs, and alternative measures to better capture dynamic stress-related processes.

Keywords: Inner speech, Stress response, Impulsivity, Emotion regulation

ÖZ

İçsel konuşma (İK) sıklığı ve buna duyulan ihtiyaç kişiler arası farklılıklar göstermekle birlikte, duygu düzenleme ve dürtü kontrol süreçleriyle ilişkili görülmektedir. Bu çalışma, İK sıklığının bireylerin duygu düzenlemesi, dürtüsel davranış ve fizyolojik stres tepkileri ile ilişkisini incelemiştir. Örneklem, 18–39 yaş aralığında 35 üniversite öğrencisinden oluşmaktadır.

İK sıklığı tüm analizlerde sürekli bir yordayıcı olarak ele alınmıştır. İK sıklığı, duygu düzenlemesi ve dürtüsellik ile ilgili öz bildirim ölçümleri, görev performansı (Stroop görevi) ve fizyolojik tepkiler (kalp atış hızı ve deri iletkenlik seviyesi) arasındaki ilişkiler korelasyon, doğrusal regresyon ve tekrarlı ölçümler ANOVA ile değerlendirilmiştir. Bulgular, İK sıklığı ile duygu düzenleme, dürtüsellik, Stroop doğruluğu ve tepki süreleri arasında anlamlı bir ilişki olmadığını göstermiştir. Görev koşulu SCL düzeyinde belirgin bir artış yaratmıştır; zihinsel aritmetik görevi, temel ve Stroop ölçümüne kıyasla daha yüksek elektrodermal aktiviteye neden olmuştur ve stres tepkisini başarılı şekilde doğrulamıştır. Bununla birlikte, regresyon analizleri, görev sırasında İK sıklığının görev sırasındaki SCL veya HR üzerinde etkisi olmadığını göstermiştir. Yalnızca temel ölçümde daha yüksek İK sıklığının daha düşük kalp atım hızı ile ilişkili olduğu bulunmuştur ($\beta = -.48$, $p = .004$, $R^2 = .23$). Genel olarak, İK sıklığı bilişsel ve fizyolojik sonuçları önemli ölçüde etkilememiştir. Gelecek araştırmalarda dinamik stres süreçlerini daha iyi yakalayabilmek için daha büyük örneklemler kullanılmalı, koşulların sunum sırası karşı dengeleme yöntemiyle düzenlenmeli ve alternatif ölçüm yöntemlerine yer verilmelidir.

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Anahtar Kelimeler: İçsel konuşma, Stres tepkisi, Dürtüsellik, Duygu düzenleme

1. Introduction

Inner speech (IS), also known as inner monologue, is the cognitive process involving self-directed verbal thoughts and is vital for self-regulation, problem-solving, and cognitive processing (Alderson-Day and Fernyhough, 2015: 931). The frequency and reliance on IS vary across individuals (Fernyhough, 2004: 49), with some depending more on non-verbal thought processes. This variability may affect self-regulation capacities, including emotion regulation and impulsive behaviour. Previous research has demonstrated a link between inner speech (IS) and impulsive responding (Tullett and Inzlicht, 2010: 255). This relationship may be explained by the role of IS in self-regulation (Alderson-Day and Fernyhough, 2015: 936). Specifically, IS enables individuals to reflect on their actions, evaluate potential consequences, and inhibit inappropriate behavioural responses. Disruption of this internal dialogue has been shown to impair inhibitory control, suggesting that individuals who engage less frequently in IS may exhibit greater impulsivity, particularly in emotionally salient contexts. However, the relationship between IS frequency and both emotion regulation and impulsivity, especially under stress-inducing conditions, has not been thoroughly examined within a unified framework.

It is very common for individuals to exhibit increased impulsive behaviour in times of stress. One of the biggest factors that influence stress is emotion, which, in turn, can be regulated through IS. According to research, individuals with a higher frequency of IS are more likely to use adaptive emotional regulation strategies, such as cognitive reappraisal, rather than suppression (Salas et al., 2018: 84). In contrast, those with lower IS frequency may struggle to regulate emotions, potentially leading to more impulsive responses when experiencing emotional distress (Aldao et al., 2010: 225). This suggests that individuals who do not actively engage in IS may have difficulties in navigating emotionally charged situations, especially when under stress.

IS also plays a crucial role in impulse control, particularly in decision-making and behaviour regulation. Suppressing IS has been found to impair cognitive control and increase impulsive behaviour (Tullett and Inzlicht, 2010: 255). Through verbal self-guidance, individuals can reflect on their emotions and actions, which facilitates greater behavioural regulation and delayed gratification (Raghunathan, 2023: 45). Additionally, stress itself affects these processes. Under high levels of stress, the prefrontal cortex (responsible for self-regulation) is compromised, leading to increased impulsivity and poor decision-making (Amy and Arnsten, 2009: 419). For example, a study showed that the ability to engage in cognitive reappraisal is reduced under stress, resulting in more emotionally driven impulsive actions (Raio et al., 2013: 15143). IS, in such contexts, may serve a protective role by helping individuals manage their emotional responses and maintain self-control.

Despite these important findings, the combined role of IS, emotion regulation, and impulsivity has not been explored in a single design that incorporates physiological and behavioural measures. This study addresses that gap by examining how individuals with varying IS frequencies respond to stress-inducing tasks. The goal is to determine whether individuals with lower IS frequency are more prone to emotional instability and impulsive behaviour. Stress in this study was operationalized through the use of Stroop and mental arithmetic tasks under time constraints, as stress responses have been shown to differ significantly between resting and task conditions, with tasks eliciting stronger physiological and psychological reactions (Lupien et al., 2007: 212).

The study aims to examine whether the frequency of inner speech is related to emotion regulation and impulsive behaviour in stressful environments. Specifically, it investigates three hypotheses: (1) IS frequency will be associated with individual differences in emotion regulation strategies, such that higher inner speech frequency will be related to greater use of adaptive emotion regulation; (2) IS frequency will be associated with impulsivity, such that lower IS frequency will be related to higher levels of impulsive behaviour; and (3) IS frequency will be associated with physiological indices of stress regulation across baseline and stress-inducing task conditions, such that higher IS frequency will be related to lower levels of physiological responses and vice versa.

By combining physiological and self-report data, this study offers a multimodal approach to understanding the role of inner speech under stress. The findings have the potential to inform psychological interventions aimed at improving emotion regulation and impulse control. If IS is shown to act as a protective factor, it may be incorporated into therapeutic frameworks, such as cognitive behavioural therapy, to enhance emotional resilience. Although numerous interventions exist for impulse control disorders, few address the cognitive underpinnings like IS that may modulate these behaviours. Furthermore, the study provides insight into IS as a coping mechanism in high-stress situations, extending the literature beyond its typical focus as a cognitive process (Tullett and Inzlicht, 2010: 255).

2. *Methodology*

2.1. Sample

The sample consisted of 35 participants between the ages of 18 and 39, 14 of whom were male and 21 were female. A randomized sampling technique was applied. The participants were university students who took part in the study on a volunteer basis. If the participants were younger than 18 or older than 39 years of age, had any neurological disorders, were using psychotropic medication, or were cognitively impaired, they fell under the exclusion criteria and were excluded.

2.2. Data Collection Tools

A *sociodemographic form* was given to the participants to determine whether they met the inclusion criteria, as well as to get more insights about the participants when the data was being analyzed.

The participants' data was collected through three self-report questionnaires. IS was measured using the *Varieties of Inner Speech Questionnaire (VISQ-R)* to evaluate the frequency and nature of IS in each participant. VISQ originally consisted of 18 items, each rated on a 6-point Likert scale (Alderson-Day et al., 2018: 49). The VISQ-R (Revised Version), however, consists of 24 items. It expands on the core 18 items by refining the subscales related to IS and their relation to psychopathology. The subscales of the VISQ-R are: Dialogic Inner Speech (DIS), Evaluative/Critical Inner Speech (ECIS), Other People in Inner Speech (OPIS), and Condensed Inner Speech (CIS).

Emotion regulation was measured using the *Emotion Regulation Questionnaire (ERQ)*. It is a 10-item self-report, and each item was rated by the participant on a 7-point Likert scale; it was developed to measure two key emotion regulation strategies: Cognitive Reappraisal and Expressive Suppression (Gross and John, 2003: 350). Cronbach's alpha for the cognitive reappraisal facet has been reported to range from .89 to .90, and from .76 to .80 for the expressive suppression facet (Preece et al., 2019: 2). Test-retest reliability over three months has previously been reported as .69 for cognitive reappraisal and .73 for expressive suppression (Gross and John, 2003; 352).

Impulsive behaviour was measured through the *UPPS-Impulsive Behaviour Scale*, which measures positive and negative urgency (26 items), premeditation (11 items), preservation (10 items), and sensation seeking (12 items). It measures the aforementioned five dimensions of impulsivity (Whiteside and Lynam, 2001: 669). Only the Positive Urgency and Negative Urgency items were utilised to measure the impulsive tendencies. Positive urgency items specifically measure the tendency to act impulsively in response to extreme positive emotions, and the Negative urgency items measure the tendency to act impulsively in response to intense negative emotions. Internal Consistency Cronbach's alpha coefficients for the subscales range from (0.61 to 0.88) (Dugré et al., 2019: 2).

The Mini-Mental State Exam (MMSE) was administered to ensure that all the participants were cognitively comparable. MMSE is a cognitive screening tool designed to assess global cognitive function and detect potential impairments (Folstein et al., 1975: 189). It is a quantitative measure and is often used in clinical and research settings. Internal consistency (Cronbach’s alpha): Ranges from 0.54 to 0.96 (Tombaugh and McIntyre, 1992: 923).

Furthermore, the stroop tasks were created using PsychoPy (version 2020.2.10) and administered online via Pavlovia. The tasks were designed as colour-identification paradigms. English spellings were used and all stimuli were presented in Arial and the size of 0.2 in Psychopy with a grey background. Participants completed a Stroop task consisting of two main conditions: a practice condition (Stroop 1), in which colour word reading was presented in black ink, and a Stroop condition (Stroop 2), in which congruent and incongruent colour-word stimuli were randomly presented within the same trial block. The practice condition was always administered first, and the order of conditions was not counterbalanced across participants. Accuracy was recorded for both conditions. The reaction time of the participants for Stroop 1 and 2 were recorded, regardless of whether they were correct or not. The first Stroop block consisted exclusively of congruent trials and served as a task familiarization phase, allowing participants to learn stimulus–response mappings and button use under minimal cognitive conflict. The second Stroop block included a mixture of congruent and incongruent trials to introduce response conflict in an unpredictable manner. Prior work demonstrates that Stroop interference is sensitive to trial composition, with designs preventing strategic adaptation and preserving robust conflict effects (MacLeod, 1991: 192).

Mental Arithmetic task was also administered; this required tasks such as asking the participant to begin at 100 and repeatedly subtract 7 as quickly and accurately as possible. For the mental stress responses, simultaneous measurement of electrocardiogram (ECG) and electrodermal activity (SCL) from left arm were monitored through BIOPAC system. ECG was used to measure heart rate both of which have a high reliability as indicators of the autonomic nervous system activation due to stress (Berntson et al., 1997: 624).

Skin Conductance Level (SCL) – This represents the slow variations in the overall skin conductance, indicative of cumulative skin humidity. Skin Conductance Response (SCR) - reflects transient changes in conductance due to external stimuli. The Autonomic Nervous System (ANS), which regulates involuntary physiological functions, comprises two main branches: the Sympathetic Nervous System (SNS), which activates during stress or danger (commonly referred to as the "fight or flight" response) and the Parasympathetic Nervous System (PNS), which predominantly activates during relaxation, counteracting the SNS.

Research studies frequently compare physiological parameters during stress and relaxation phases to analyze stress responses. While SCL will be the primary measure for stress detection, Heart Rate (HR) was collected to support the labeling stage. HR is an indicator of autonomic regulation, where decreased HR is associated with increased sympathetic activity or decreased parasympathetic activity.

To record HR, electrocardiogram (ECG) signals were acquired using disposable Ag/AgCl electrodes placed on the legs and arms to detect electrical impulses from the heart. The BIOPAC® MP36 system was used for ECG acquisition at a sampling frequency of 500 Hz. The time interval between successive heartbeats was analyzed to assess HR.

2.3. Procedure

This study had an experimental research design as it took place in the cognitive and affective neuropsychology laboratory at Işık University. A convenience sampling method was used among university students enrolled in programs where English was the language of instruction, so that their fluency was guaranteed. They had all passed the Işık University English Proficiency Exam, as all of the questionnaires and tasks were to be conducted in English. The participants were given the VISQ-R online through Google Forms. Their responses were then scored according to the VISQ-R guidelines, yielding a continuous total IS score for each participant, with higher scores indicating greater frequency of IS. Descriptive statistics were computed to summarize the distribution of IS scores within the sample.

Along with the VISQ-R, in the same Google form, the participants were also asked to fill out a sociodemographic form to ensure that they did not fall under the exclusion criteria, as well as an informed consent form, in which they agreed to volunteer and participate in the study.

Upon arriving at the laboratory, the MMSE was administered, after which, the participants were asked to fill out the UPPS and ERQ through Google Forms. Afterwards, they were hooked up to the ECG (Electrocardiogram) to measure the participant's heart rate and the EDA to measure the sweat production of the participants' hands to monitor stress response during stress-inducing tasks.

The experiment consisted of two phases: **Baseline Phase**: Participants were guided to a relaxed state to establish a physiological baseline. They were asked to silence their phones, sit comfortably, close their eyes, and engage in slow, deep breathing for five minutes before the task began. **Stress-Induction Phase**: Participants engaged in a stress- inducing task while physiological signals were recorded. The phase began with a mental arithmetic task lasting 2 minutes, during which participants solved rapid basic math problems under time pressure. When the allotted time ended, loud alarms were played to further induce stress.

This was followed by two Stroop tasks:

2.3.1. Stroop 1 (Grayscale Reading Task; 10 minutes):

Participants viewed colour words presented in grayscale font and were instructed to read the word and press the corresponding response button. Green, yellow, red, blue mapped to the keys s, d, a, and f, respectively. There were no congruent or incongruent conditions in this reading task. Each trial lasted approximately 1.3 s on average. Stimuli remained on the screen until a response was made. No additional inter-stimulus interval was implemented between trials (frame-to-frame transition ≈ 3–4 ms). Stroop 1 was designed with 519 target stimuli to help participants familiarize themselves with the keyboard required to perform the Colour-Word Stroop task. This ensured that any mistakes made in Stroop 2 were due to stress rather than the participants not being familiar with the keyboard.

2.3.2. Stroop Task 2 (Colour–Word Task; 5 minutes):

Participants viewed colour words presented in coloured font (green, yellow, red, blue) and were instructed to ignore the written word and respond based solely on the font colour, pressing the appropriate button. Each trial lasted approximately 1.3 s on average. Stimuli were presented on the screen until a response was made, and no additional inter-stimulus interval was implemented between trials (frame-to-frame transition ≈ 3–4 ms). The Colour-Word Stroop task consisted of 207 target stimuli (103 were congruent and 104 were incongruent). The mix of incongruent and congruent target stimuli was done to prevent strategic adjustment and expectancy-based responding, thereby preserving genuine interference effects. If participants know all trials are incongruent, then they are likely to adapt and interference shrinks. If trials are mixed, then conflict is unpredictable, so incongruent trials would elicit true cognitive control demands.

2.3.3. Physiological recording continued uninterrupted throughout the entire stress-induction phase:

The BIOPAC MP36 hardware (Biopac Systems Inc., USA) was used to collect physiological data at a sampling rate of 500 Hz. EDA signals were recorded using gel electrodes placed on the ring and middle finger of the non-dominant hand to minimize movement-related disturbances. Physiological data was recorded throughout each task condition, as well as baseline phase to establish the base standard for each participant's readings. Mean SCL and HR parameters obtained from these were compared across conditions.

The stress was induced by giving the participants (the Stroop test and Mental Arithmetic tasks). These were used to assess the participants' cognitive performance under pressure. The participants were asked to respond to stimuli as quickly and accurately as possible. Although no explicit upper time limit was imposed for individual responses, the continuous and rapid task structure itself created time pressure and acted as a cognitive stressor.

Additionally, white noise at 70 dB was presented continuously during the stress-induction phase as it is commonly used to increase physiological stress responses in cognitive and psychological research (Radun, 2022: 4); prolonged noise exposure can also lead to heightened emotional reactivity and discomfort (Weinstein, 1978: 458).

2.4. Variables

Dependent variables**:** Stress reaction taken by EDA and ECG (microsiemens and heartbeat).
Independent variables: Stress-inducing tasks, IS frequency, Time on stress reaction.

2.5. Data Analysis

The collected data was then uploaded onto SPSS software (Version 30; IBM Corp.) for statistical analyses. Analyses included data from self-report questionnaires, Stroop task performance, and physiological measures (HR and SCL) recorded during stress-inducing tasks.

Linear regression analyses were conducted to examine whether inner IS frequency predicted ERQ and UPPS-P scores. IS frequency was treated as a continuous predictor variable in all analyses. Pearson correlation analyses were also conducted to examine associations between

VISQ-R scores and ERQ scores. Assumptions for linear regression were assessed prior to analysis. Skewness (–.133, SE = .398) and kurtosis (–.218, SE = .778) values for IS scores indicated no substantial deviations from normality. Linear regression analyses were also conducted to examine whether IS frequency predicted SCL and heart rate across baseline and task conditions.

The participants' errors in the Stroop and mental arithmetic tasks were also recorded and analyzed to examine their associations with their IS frequency. The Stroop task performance measures were calculated using mean reaction times rather than raw accuracy counts. Because the number of target stimuli differed between the two tasks – 519 target stimuli in the practice colour-word reading task (Stroop 1) and 207 target stimuli in the colour-word task (Stroop 2). Reaction time provided a more comparable metric than percentage accuracy. Importantly, the Stroop 1 task is not meant to be a stress inducing task there for no stroop effect will be calculated by the difference in the scores of Stroop 1 and Stroop 2. Stroop Effect was calculated using the correct responses from Stroop 2, whereby subtracting the reaction time of incongruent stimuli with congruent stimuli and multiplying it with 1000 to achieve the millisecond values ((Incongruent rt minus congruent rt)*1000 = Stroop effect). Stroop performance was operationalized using interference scores derived from reaction times in Stroop 2. Accuracy and Stroop 1 performance were recorded but not included in inferential analyses.

Repeated measures analyses were conducted to assess within-subject differences in physiological responses across conditions, using IS frequency as a continuous variable. Physiological signals were recorded using the BIOPAC MP36 system and exported to Microsoft Excel for preprocessing, as the system is primarily designed for data acquisition rather than advanced statistical analysis. From the EDA and ECG recordings, skin conductance level was extracted as baseline-corrected changes (ΔSCL, in microsiemens, μS), along with heart rate (in beats per minute, BPM).

For each task condition, BIOPAC-derived values for SCL were calculated via changes in electrodermal activity. The data were expressed in microsiemens (μS) and baseline-corrected prior to analysis. Therefore, the reported values reflect changes relative to baseline (ΔSCL), rather than absolute tonic conductance levels. Mean physiological values for baseline and stress task phases were then computed and compared to assess stress-induced changes across conditions. In addition, IS frequency was treated as a continuous variable and examined in relation to physiological measures using correlation and linear regression analyses.

Additionally, the cut-off score for the MMSE is 27/30 for use with healthy adults or in studies where cognitive functioning in a non-impaired population is expected; this was to exclude those with mild cognitive impairments (Folstein et al., 1975: 197).

3. Results

3.1. Descriptive Statistics and Associations Between Inner Speech, Emotion Regulation, and Impulsivity

All participants completed the Mini-Mental State Examination (MMSE) and met the established cut-off score, indicating no evidence of cognitive impairment within the sample.

Descriptive statistics were computed for ERQ, UPPS-P, and VISQ-R scores. IS frequency was treated as a continuous variable in all analyses. Pearson correlation and linear regression analyses were conducted to examine associations between IS frequency and ERQ and UPPS-P scores.

Results indicated no significant association between overall IS frequency and ERQ scores ($p > .05$). Similarly, IS frequency did not significantly predict UPPS-P total scores ($p > .05$).

VISQ-R subscales (Dialogic Inner Speech, Evaluative/Critical Inner Speech, Other-People Inner Speech, and Condensed Inner Speech) were examined descriptively and included as continuous predictors in exploratory analyses. Higher IS frequency was reflected in higher scores across all VISQ-R subscales, consistent with the dimensional structure of the questionnaire, refer to Table 1.

Table 1

Descriptive Statistics

	IS_TOTAL	ERQ_TOTAL	UPPS_TOTAL	DIS	ECIS	OPIS	CIS
Mean	142.8	46.89	57.40	4.132	3.906	4.337	4.651
Std. Deviation	28.71	7.753	13.68	1.018	0.982	0.914	0.947
Minimum	88.00	28.00	33.00	1.875	2.000	2.000	2.800
Maximum	211.0	63.00	84.00	6.625	5.857	6.400	7.000

Note: DIS = Dialogic Inner Speech; ECIS = Evaluative/Condensed Inner Speech; OPIS = Other- People Inner Speech; CIS = Condensed Inner Speech; SD = Standard Deviation.

3.2. Electrodermal Activity Across Task Conditions

A repeated-measures ANOVA revealed a significant main effect of task condition on skin conductance changes (ΔSCL), *F*(3, 102) = 28.91, $p < .001$. Bonferroni-corrected post hoc comparisons indicated that SCL was significantly higher during the mental arithmetic task compared to baseline and both Stroop conditions (all *p*s < .001), with large effect sizes, as shown in Table 3. No significant differences were observed between the Stroop conditions. This pattern of elevated SCL during mental arithmetic indicates increased stress levels, followed by reduced physiological arousal during subsequent tasks.

Exploratory analyses examining whether individual differences in IS frequency moderated SCL responses indicated no significant interaction between IS frequency (continuous) and task condition (p > .05). Thus, changes in EDA across conditions were not associated with IS frequency.

Table 2

Mean ΔSCL Across Baseline and Task

Condition	Mean ΔSCL (µS)	Std. Deviation
Baseline SCL	-0.003	.043
Mental Arithmetic SCL	0.100	.093
Stroop 1 SCL	-0.005	.016
Stroop 2 SCL	0.003	.025

Note: SCL: Skint Conductance Level. SCL values are expressed as change from baseline (ΔSCL); negative values indicate decreases relative to baseline.

Table 3

Pairwise Comparisons (Bonferroni Corrected)

Comparison	Mean Difference (µS)	*p* (corrected)	Cohen's *d*
Mental Arithmetic SCL vs Baseline SCL	+0.105	< .001	1.98
Mental Arithmetic SCL vs Stroop 1 SCL	+0.105	< .001	2.00
Mental Arithmetic SCL vs Stroop 2 SCL	+0.097	< .001	1.84

Stroop 1 SCL vs Baseline SCL	−0.002	> .999	0.05
Stroop 2 SCL vs Baseline SCL	+0.006	.471	0.14
Stroop 1 SCL vs Stroop 2 SCL	−0.009	.276	0.32

3.3. Inner Speech Frequency and its Relationship with Physiological Responses

Linear regression analyses were conducted with inner speech IS frequency entered as a continuous predictor. Separate regression models were computed for each of the four task conditions for electrodermal activity (EDA/SCL) and heart rate (BPM). Across these analyses, IS frequency did not significantly predict physiological responses in any task condition (all ps > .05).

The sole significant effect emerged for baseline heart rate. IS frequency significantly predicted resting heart rate, $\beta = -.48$, $p = .004$, $R^2 = .23$, indicating that higher self-reported inner speech frequency was associated with lower baseline heart rate as shown in Table 4.

Table 4

Linear Regression Predicting Baseline Heart Rate (BPM) From Inner Speech Frequency

Predictor	B	SE B	β	t	p
Intercept	137.50	0.62	—	221.70	< .001
IS Score	−0.013	0.004	−0.48	−3.11	.004

Note: Baseline heart rate measured in beats per minute (BPM). B: unstandardized regression coefficients; β: standardized coefficients

3.4. Stroop Task Performance and Inner Speech

A Stroop interference score was calculated for each participant by subtracting mean reaction time for congruent trials from incongruent trials within Stroop 2. Pearson correlation analysis indicated that Stroop interference was not significantly associated with IS frequency, $r = .18$, $p = .303$, indicating that IS frequency was not related to individual differences in interference magnitude. Please refer to Table 5.

Table 5

Correlation Between Inner Speech Frequency and Stroop Interference (incongruent – congruent, ms)

Variables	r	p	95% CI

IS frequency – Stroop effect (ms)	.18	.303	[–.16, .48]

Note: ms: millisecond

3.5. ERQ and UPPS Scores and Their Associations with Physiological Measures

Pearson correlation analyses were conducted to examine associations between ERQ scores and physiological indices of stress. ERQ scores were not significantly associated with baseline skin conductance level or heart rate (ps > .05). However, a significant positive association was observed between ERQ scores and skin conductance level during the mental arithmetic task, r(33) = .34, p = .049, indicating that greater self-reported use of emotion regulation strategies was associated with higher sympathetic arousal during acute stress. ERQ scores were not significantly associated with heart rate during the mental arithmetic task (p > .05), refer to Table 6. Pearson correlation analyses were also conducted to examine the relationship between UPPS scores and the physiological measures, however, no significance was found.

Table 6

Pearson Correlations Between ERQ Scores and Physiological Measures

Association	r	p
ERQ – baseline EDA	−0.096	.581
ERQ – mental EDA	0.336	.049
ERQ – baseline BPM	−0.228	.188
ERQ – mental BPM	0.129	.461

4. Discussion

While previous literature had exhibited a strong association between IS and self-regulation capacities, suggesting that IS may influence and have a positive effect on emotional and behavioural control under stress (Tullett and Inzlicht, 2010: 255), the findings in this study seem to only partially support this.

Consistent with Hypothesis 3, which predicted that individuals would exhibit a change in their physiological response before and during the stress-induced tasks, a significant association was observed between higher IS frequency and lower baseline heart rate. This finding suggests that IS frequency may be related to resting autonomic regulation, rather than dynamic stress reactivity. One possible explanation is that individuals with higher IS frequency engage more frequently in internal self-guidance and reflective processing, which may promote greater baseline parasympathetic activity and overall autonomic stability. IS has been linked to self-regulatory processes, including planning and cognitive control (Alderson-Day and Fernyhough, 2015: 936), which may extend to physiological functioning at rest. In this sense, higher IS frequency may reflect a trait-like tendency toward internal control that manifests in lower resting heart rate (Thayer and Lane, 2000: 216).

Additionally, skin conductance changes (ΔSCL) increased significantly only during the mental arithmetic task, with no significant increases observed during the Stroop conditions, suggesting that the arithmetic task elicited a stronger autonomic response than the subsequent Stroop tasks. This aligns with previous work identifying SCL as a sensitive indicator of autonomic arousal under stress (Karthikeyan et al., 2011: 423). However, variability in physiological stress responses across tasks was not meaningfully explained by IS frequency.

The lack of association between IS frequency and physiological stress responses may be explained by several factors. First, the sensitivity of the physiological measures used may not have been sufficient to detect subtle individual differences linked to IS. Second, the fixed task order likely introduced habituation effects, with participants showing the strongest physiological response during the initial mental arithmetic task, followed by reduced responsiveness in later tasks. This pattern suggests that the observed differences may reflect adaptation to the experimental context rather than task-specific stress reactivity. It is possible that IS primarily influences cognitive and emotional processes whereas skin conductance indexes general autonomic arousal, which may not be directly sensitive to such individual differences. This dissociation may explain the absence of physiological differentiation across IS levels. Finally, it is also possible that the influence of IS is more closely linked to transient or phasic physiological responses, or to neural measures, rather than to tonic changes in skin conductance as assessed in the present study.

However, Hypothesis 1, which predicted that higher IS frequency would be associated with greater use of adaptive emotion regulation strategies, was not supported. Analyses treating IS frequency as a continuous variable revealed no significant association between IS frequency and emotion regulation as measured by ERQ. Similarly, Hypothesis 2, which predicted that lower IS frequency would be associated with higher levels of impulsive behaviour, was also not supported. IS frequency did not significantly predict impulsivity scores on the UPPS-P. These results suggest that impulsivity may be influenced by regulatory mechanisms that are not directly captured by self-reported IS frequency. Alternatively, IS may play a more situational or task-dependent role in impulse control that is not reflected in trait-level impulsivity measures.

The absence of differences in physiological stress responses across IS frequency groups suggests that IS may not directly modulate autonomic reactivity under acute stress. Instead, IS may exert its influence at a cognitive or interpretive level, shaping how individuals appraise and respond to stress rather than altering physiological activation itself. This distinction aligns with models of emotion regulation in which cognitive strategies do not always produce immediate reductions in physiological arousal, particularly during demanding tasks (Gross, 1998: 282; Kreibig, 2010: 420).

Regression analyses also indicated that IS frequency did not significantly predict Stroop interference scores. These findings suggest that higher IS frequency does not confer a consistent performance advantage in interference control tasks. This result should be interpreted cautiously given the non-standard structure of the Stroop task used in this study, including unequal trial numbers and an extended familiarization phase, which may have introduced fatigue or habituation effects and reduced sensitivity to individual differences. These null associations between IS frequency, impulsivity, and emotion regulation do not support previous studies (Alderson-Day and Fernyhough, 2015: 936).

The increase in SCL observed during the mental arithmetic task is consistent with prior research demonstrating that SCL is a robust and sensitive measure of autonomic arousal under stress (Gupta et al., 2023: 252; Luzzani et al., 2025: 253). Importantly, the fixed sequencing of the mental arithmetic task followed by the Stroop tasks likely influenced the pattern of physiological responses observed. The heightened arousal during the arithmetic task may reflect an initial stress response to task onset, while reduced responses in subsequent tasks may indicate habituation or adaptation. Therefore, differences between tasks should be interpreted cautiously, as they may reflect order effects rather than inherent differences in stress induction. These findings add to the validity of the stress-induction procedure and align with reviews emphasizing SCL's reliability in detecting heightened sympathetic activation during cognitively demanding or stressful tasks (Karthikeyan et al., 2011: 423).

Furthermore, a significant and moderate positive correlation was found between SCL and ECG responses during the mental arithmetic task. The association was attenuated and non-significant when IS was accounted for, suggesting that the coupling between autonomic measures was not robust to individual differences in IS frequency within the present sample.

Additionally, emotion regulation scores were positively associated with skin conductance during the mental arithmetic task. Rather than indicating dysregulation, this finding may reflect greater engagement with the stressor among individuals reporting higher use of emotion regulation strategies. Previous work has suggested that adaptive regulation does not necessarily dampen physiological arousal, particularly during cognitively demanding tasks, but may instead support sustained task engagement (Gross, 1998: 282).

5. Limitations and Considerations for Future Research

To explain these discrepancies, several factors should be considered. The sample size was small, consisting of only 35 participants, which may have limited the study's ability to detect subtle effects of IS. However, it is also possible that there is genuinely no relationship between IS and physiological responses. In case of null findings, alternative explanations should be considered. For example, IS may have influence on cognitive domains such as planning or problem solving (Fernyhough and Borghi, 2023: 1180; Baron et al., 2022: 15), however, has limited effects on autonomic physiological reactions. Consistent with this interpretation, Stroop task performance did not show significant association with IS frequency. This would suggest that IS did not provide a measurable advantage in cognitive control in this sample.

It is also possible that the ERQ and UPPS measures were not sensitive enough to reliably distinguish between IS frequencies. This concern reflects a broader issue in the literature: while self-report measures tend to show strong internal consistency, their validity is limited. For instance, it was found that widely used IS questionnaires display good reliability but weak convergent validity, raising concerns about whether they capture the full range of IS experiences (Uttl et al., 2011: 1719) Similarly, more recent work has emphasized that these tools may be reliable but only partially valid in representing dynamic or situational aspects of IS (Racy et al., 2022: 999). Future studies should therefore consider combining self-report instruments with alternative methods such as think-aloud protocols or experience sampling to better capture individual differences in IS.

While the mental arithmetic task was effective in inducing stress, no other significance was observed in the Stroop tasks. One explanation could be the task order. All participants received the mental arithmetic task first, followed by Stroop 1, then Stroop 2 tasks.

The fixed order of tasks likely introduced habituation, fatigue, or learning effects, attenuating physiological responsiveness in later trials. However, the ordering was intentional: the congruent-only block functioned as a familiarization phase, whereas the mixed-condition block was designed to elicit unpredictable cognitive conflict. Presenting the experimental block first may have attenuated Stroop interference due to learning or strategic adaptation. Thus, the stronger stress response observed during the mental arithmetic task compared to the Stroop tasks may reflect experimental design limitations rather than true task differences in stress induction. Future studies could address this limitation by including additional baseline measures or between-subjects counterbalancing designs where appropriate.

Additionally, limitations related to the Stroop task design should be acknowledged. In this study, Stroop 1 was intended as a familiarization phase; however, this phase was substantially longer than the subsequent Stroop task. As a result, Stroop 1 likely imposed considerable cognitive load rather than serving as a neutral practice block, potentially contributing to fatigue, habituation, and reduced sensitivity to interference effects in later task phases. Although the task order and structure could not be modified post hoc, future studies would benefit from implementing a shorter familiarization procedure that is repeated as needed to ensure task comprehension while minimizing cognitive demand and fatigue. Additionally, it should also be noted that the primary significant finding emerged for baseline heart rate, which was measured prior to task exposure and therefore cannot be attributed to task order or fatigue effects. Heart rate values were generally elevated, which may be related to anxiety associated with the laboratory environment.

In order to improve the research design and build upon previously existing research with more accuracy and reliability, the sample size should be increased, and participants from a more diverse population should be included rather than just university students. This will help increase generalizability and statistical power. Additional methods of measurement of IS could be included, such as think-aloud protocols for better accuracy. As well as counterbalancing the task order to prevent participants from exhibiting habituation effects during the stress-inducing tasks. To also measure the physiological responses much more clearly, future research could benefit from prescribing the participants with tasks that may elicit stronger physiological reactions.

Author Contribution Statement

Data collection was primarily conducted by Zayna Kaleem (40%). The conceptualization and design of the study were carried out collaboratively by Zayna Kaleem and Zeynep Küçük under the supervision of Zeynep Küçük (30%). Data analysis, interpretation of findings, drafting of the manuscript, and critical revision were performed jointly by both authors (30%). The final version of the manuscript was reviewed, approved, and agreed upon by all authors, who take full responsibility for its content.

Conflict of Interest

The authors declare no conflict of interest.

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