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Response inhibition and self-reported crashes in young Indonesian motorcyclists

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Abstract

Response inhibition, the ability to suppress inappropriate responses in goal-directed behavior, is one of the cognitive abilities associated with driving performance. This study investigated differences in response inhibition based on self-reported crashes in young Indonesian motorcyclists. Response inhibition was assessed using STOP-IT, an open-source software to run stop-signal tasks and analyze the data, which has been adapted and validated for use in Indonesian samples. The participants comprised 67 motorcyclists aged 19-25 with normal or corrected-to-normal vision and right-handed. The findings showed a significant difference in response inhibition based on self-reported crashes in the past year. Participants who had not been involved in a crash demonstrated better response inhibition than those who had. However, response inhibition did not differ significantly when considering self-reported crashes from the past three years, five years, or overall riding history. While further research is needed, the findings support an association between response inhibition and driving performance. Given that response inhibition continues to mature during adolescence, the government, parents, and schools should collaborate to strengthen the implementation of minimum driving age regulations.

Keywords

Response inhibition, Self-reported crashes, Motorcyclist, Indonesia

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Introduction

Executive function refers to high-level cognitive processes that allow individuals to regulate their thoughts and actions in goal-directed behaviour [1]. It is widely accepted that executive function consists of three main components, i.e., inhibitory control, working memory, and cognitive flexibility [1], [2]. These three main components form the foundation for other higher-level executive functions, such as reasoning, problem-solving, and planning [2]. Inhibitory control itself consists of interference control and response inhibition.

Response inhibition supports flexible behaviour in a constantly changing environment, allowing individuals to stop actions irrelevant to their goals and potentially replace them with more appropriate ones [3]. This irrelevant response can include a dominant, reflexive, or automatic response. Some researchers refer to response inhibition as “behavioral inhibition,” “motor inhibition,” “prepotent response inhibition,” and “(attention) restraint” [4].

Response inhibition deficit can contribute to various psychopathological and impulse-control disorders [5]. A meta-analysis revealed that deficits in response inhibition significantly influence several psychopathologies, including attention-deficit hyperactivity disorder (ADHD), obsessive-compulsive disorder, schizophrenia, and reading disabilities. Another meta-analysis indicated that this deficit in response inhibition is also present among individuals with substance use disorders, including drug addicts, alcohol addicts, and pathological gamblers [6], [7].

Poor response inhibition also affects healthy young individuals’ daily behaviours, including driving. A review summarizes that poor response inhibition is associated with unsafe driving behaviour, such as receiving traffic tickets, speeding, poor lane maintenance, and running red lights [8]. This cognitive ability is also related to driver performance when facing road hazards. A scoping review also revealed that response inhibition is a cognitive ability positively associated with drivers’ decision-making when experiencing traffic conflict [9]. Drivers with lower response inhibition tend to be slower in detecting road hazards [10], [11], slower in avoiding hazards, and even tend to experience more collisions in simulated driving [11]. However, investigations regarding the role of response inhibition on driving performance are still very open.

As with global safety conditions, motorcyclist safety is a challenge in itself, along with its ability to facilitate the mobilization of the Indonesian people [12]. In Indonesia, motorcyclist deaths even reached 74% of the total deaths due to traffic accidents in 2016 [13]. Therefore, investigations into factors that may affect motorcyclist safety are important to conduct, one of which is response inhibition.

Response inhibition studies in Indonesia are still limited. Assessment of cognitive inhibition using the Stroop test tend to be more frequently conducted [14], [15], [16], [17]. The assessment of response inhibition is also more commonly conducted using the go/no-go task [17], [18], [19] rather than the stop-signal task [20]. Among these studies, none have specifically linked response inhibition to motorcyclist safety.

With the above background, this study aims to investigate differences in response inhibition based on self-reported crash involvement among young Indonesian motorcyclists. This focus is particularly relevant given the low level of motorcyclist safety [13], especially among young people. As noted in the literature, response inhibition, which continues to mature during adolescence [2], [21], is associated with risky driving behavior [8] and overall driving performance [9]. However, empirical studies examining response inhibition among motorcyclists, particularly in the Indonesian context, remain limited.

In this study, response inhibition was assessed using STOP-IT [22], which was previously adapted and validated for Indonesians. Meanwhile, crash involvement was determined through self-reported crashes, a method commonly employed in traffic safety research [12]. The findings are expected to be a foundation for developing interventions to enhance motorcycle riding safety.

Method

Participants

We employed a purposive sampling technique to select participants, including cadets and employees from the Politeknik Keselamatan Transportasi Jalan and the surrounding community. Participant recruitment was conducted online, with the registration form providing research information and obtaining informed consent.

The participants comprised 69 right-handed motorcyclists with normal or corrected-to-normal vision. One participant was excluded for not complying with the procedures, and another was excluded due to an error in data recording. Therefore, 67 participants were eligible for analysis.

The participants were aged 19-25 (M = 21.5, SD = 1.6). They started riding motorcycles between the ages of 10 and 14 (M = 14.6, SD = 2.1). The most of participants rode scooters (79.1%). Table 1 presents the characteristics of the participants.

Table 1. Characteristics of the participants

Variables		***n*** **(%)**
Sex	Female	33 (49.3)
	Male	34 (50.7)
Status	Cadets	27 (40.3)
	Non-cadets	25 (37.3)
	Employees	15 (22.4)
Riding license	No	17 (25.4)
	Yes	50 (74.6)
Riding frequency	Never	8 (11.9)
	Rarely (1-2 days)	8 (11.9)
	Sometimes (3-4 days)	9 (13.4)
	Often (>4 days)	42 (62.7)

Measurement

1. Stop-signal task

We have adapted and validated STOP-IT, an open-source software that can run stop-signal tasks and analyze the data [22]. We created two versions of the STOP-IT design with different stop-signal time intervals. Version 1 used default variables, while version 2 used variables based on previous studies [5], [24], [25], [26]. This report refers to version 2.

The main task of the stop-signal task consisted of a simple two-choice task, where participants were presented with two white arrows pointing right and left as go stimuli [22]. During go trials, participants were instructed to respond quickly by pressing the corresponding arrow keys on the keyboard. In stop-signal trials, which constituted 25% of all trials, the arrow turned red (i.e., a stop-signal) after varying stop-signal delay (SSD). The SSD was continuously adjusted using a staircase tracking procedure: successful inhibition led to an increase of 50 ms in SSD, while unsuccessful inhibition led to a decrease of 50 ms. Participants were instructed to withhold or cancel their responses upon the appearance of the stop signal. The instructions emphasized the importance of quick and accurate responses without waiting for the stop signal while also acknowledging the potential difficulty of responding correctly in its presence

This inhibition task consists of two phases, i.e., the training phase, which consists of one block with 40 trials, and the main phase, which consists of five blocks with 480 trials. This trial count was sufficient to reveal individual differences [22] while mitigating participant fatigue. During the training phase, direct feedback is provided for 750 ms, including input for incorrect, late, and premature responses and reminders to stop when inhibition was unsuccessful. A 15-second break separated each block, during which participants received performance feedback from the preceding block.

Each trial began with the appearance of a fixation cue, which was replaced by a go-stimulus after 500 milliseconds (fixation presentation variable or FIX) [22]. The duration of the inter-stimulus interval was 1000 milliseconds (fixed blank intertrial interval variable or ITI). The go-stimulus remained on the screen until the participant responded or until 1250 milliseconds (maximum reaction time) had elapsed. The initial SSD was set at 250 milliseconds and was continuously adjusted using a staircase tracking procedure. Figure 1 illustrates the stop-signal task procedure.

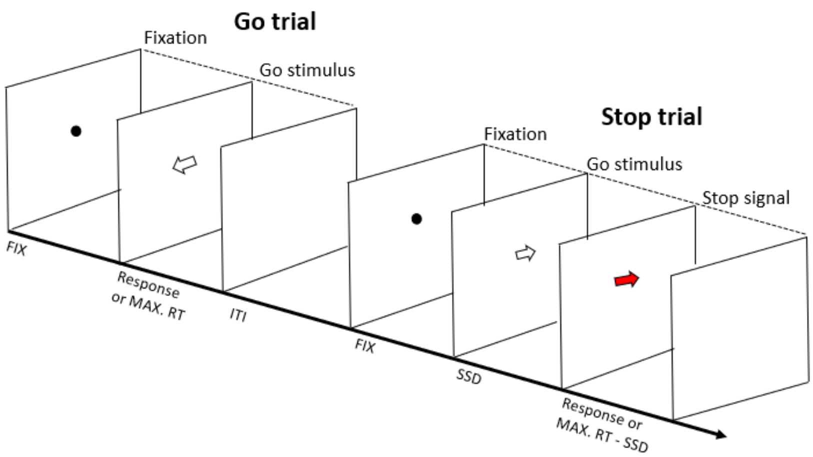

Figure 1. Stop-signal task (modified from Verbruggen et al. [22])

The stop-signal task then generates a stop-signal reaction time (SSRT). SSRT is the time required to withhold a response after seeing a stop signal [11]. Longer SSRTs indicate decreased response inhibition, indicating a poorer ability to suppress inappropriate responses.

2. Questionnaires

Demographic and motorcycle riding experience questionnaires were administered at the end of data collection. The questionnaires included the following questions: age, gender, status, initial riding age, motorcycle type, riding frequency in one week, motorcycle riding license, and crash involvement.

Procedures

We conducted this study at the computer laboratory of Politeknik Keselamatan Transportasi Jalan. Each data collection session was conducted in groups, with 3-6 participants in each session. Participants sat at the computer in the order they arrived, positioned approximately 70 cm before the computer screen. Before starting the stop-signal task, the instructor explained the instructions and allowed participants to ask. The study lasted approximately 20 minutes. After a 15-minute break, participants proceeded to Session 2, which involved additional data collection for a separate purpose. Its results will be reported independently. All participants received a total compensation of IDR 25,000 for completing both sessions. This research obtained approval from the Ethics Commission of the Faculty of Psychology, Universitas Gadjah Mada.

Data analysis

We estimated SSRT following the guidelines of Verbruggen et al. [22]. The analysis was executed via the 'R Shiny' app. SSRT was estimated using the integration method with the replacement of omissions. SSRT is not estimated when the race model assumptions are violated, namely when the reaction time in unsuccessful stop-trials is longer than in go-trials. Additionally, we applied lenient outlier criteria established by Congdong et al. [24]. Shorter SSRT indicates higher response inhibition ability.

We estimated the reliability of SSRT using a split-half approach, employing Intra-class correlation (ICC) [21], [24]. We divided the individual data into groups based on left and right arrow stimuli. ICC estimation followed the convention McGraw and Wong outlined [27], using a mean-rating, consistency, 2-way mixed-effects model. Interpretation of the ICC coefficient is based on the criteria of Koo and Li [28]. A higher ICC coefficient indicates greater consistency of the SSRT scores between the left and right arrow stimuli. ICC analysis was performed using SPSS version 25.

Finally, we examined SSRT based on demographics by testing the correlation between SSRT and age and the differences in SSRT based on sex and status (i.e., cadets, non-cadets, and employees). Additionally, we also tested for differences in SSRT based on self-reported crashes. Hypothesis testing was carried out using a two-tailed test with the level of statistical significance set at .05. Assumption tests were carried out using Levene's test for homogeneity and Shapiro-Wilk for normality. These analyses used JASP version 18.3 [29].

Results and discussion

Results

1. The adaptation and validation of the STOP-IT instruction

The adaptation and validation of the STOP-IT instructions began with a forward translation by one linguist and two psychologists proficient in English. The three results were then synthesized by a fourth expert (a linguist) and the first author. The synthesis included adjustments to the language style and resolving differences in translating specific terms. For example, "go-trials" and "stop-trials" were retained in English because they were considered technical terms that would be ambiguous if translated. Next, a backward translation was carried out by two linguists. Discrepancies in the backward translation were resolved through consensus, such as in the translation of the phrase "umpan balik langsung".

Four psychologists and one linguist then evaluated the final translation results. The evaluation used questions adapted from Hambleton and Zenisky [30]. Next, the experts' agreement was tested using the Intraclass Correlation Coefficient (ICC), and an ICC coefficient of 0.717 was obtained, which indicates a moderate level of agreement [28]. The experts considered the translation accurate but suggested improvements to align with the target language style.

Finally, the second expert assessment resulted in minor revisions, such as replacing the word "eksperimen" with "tugas," to align with the measurement objectives. One expert also suggested removing performance information at the end of the block to avoid learning effects. However, this information was retained because it was in line with the recommendations in the guideline [22]. In addition, practice was also shown not to improve stop-signal task performance [5]. This expert assessment was conducted by three experts in the field of psychology. The complete adaptation and validation process can be accessed via https://osf.io/683g4/.

2. Outlier analysis and reliability

The stop-signal reaction time (SSRT) analysis was performed following the guidelines of Verbruggen et al. [22] , with outlier determination based on the lenient criteria suggested by Congdon et al. [24]. The lenient outlier criteria include: stop-trial inhibition less than 25% or greater than 75%, 2) go response less than 60%, 3) go errors greater than 10%, 4) SSRT estimate that is negative or less than 50 ms. Data from the 67 participants did not show any violations of the race model or outliers.

Next, reliability testing was conducted using a split-half approach involving two parts: response groups for right and left arrow stimuli. Lenient outlier criteria were applied to identify outliers on both sides of the data; if at least one side meets the outlier requirements, then the data is excluded. The obtained ICC coefficient was .72, indicating moderate reliability [28].

3. The difference of response inhibition based on demographics

The Pearson's correlation analysis revealed no significant correlation between SSRT and age, $r = -.11$, $p = .36$, 95% CI [-.34, .13]. No significant differences in SSRT were found either based on sex ($M_{male} = 234.12$, $SD_{male} = 47.5$, $M_{female} = 248.47$, $SD_{female} = 38.31$), $t(65) = -1.355$, $p = .18$, or among status groups, ($M_{cadets} = 243.63$, $SD_{cadets} = 32.74$, $M_{employees} = 234.27$, $SD_{employees} = 62.96$, $M_{non\text{-}cadets} = 243.28$, $SD_{non\text{-}cadets} = 40.69$).

4. The difference of response inhibition based on self-reported crashes

The difference in SSRT scores based on self-reported crashes was examined across several periods, namely crashes in the last year, the last three years, the last five years, and since the beginning of motorcycle riding. Table 2 presents the statistical test results for each of these periods. For comparisons between the two groups, the independent sample t-test and the Mann-Whitney U test were used for parametric and non-parametric data, respectively. For comparisons involving more than two groups, one-way ANOVA was applied. Significant differences were found only for crashes in the past year.

Discussion

This study investigated differences in response inhibition in young motorcyclists based on their crash involvement. Response inhibition was measured using STOP-IT, an open-source software for running and analyzing stop-signal task data [22]. STOP-IT has been adapted and validated for use in a young Indonesian sample. The reliability was consistent with previous research (*e.g.,* average ICC of .71 [24]).

The findings showed no differences in response inhibition based on demographics. First, no significant correlation was found between SSRT and age. This result is consistent with existing literature, which suggests that response inhibition matures during adolescence and declines during normal ageing [2], [21], [31]. The participants in this study were between 19 and 25 years old. Within this age range, response inhibition typically has typically reached maturity, which may explain the absence of a significant correlation. Studies with samples spanning a broader age range may enable the identification of the relationship [32].

Second, there are no differences in response inhibition between males and females. These results are consistent with previous studies [21], [33]. Differences in response inhibition between males and females were found in the younger age group but not in the older one. The absence of differences in the older age group may be attributed to mature response inhibition within this age range [2], [21], [31].

Third, there is no significant difference in response inhibition between Politeknik Keselamatan Transportasi Jalan cadets, employees, and the general public. Although cadets have different characteristics from other groups (for example, living in a dormitory with strict rules), this does not differentiate their response inhibition ability from other groups. This finding may also be due to the relatively homogeneous age range of the participants.

Table 2. SSRT based on self-reported crashes

Self-reported crashes	*n*	Mean (SD)	Statistic test
In the past year			
No	61	238.02 (43.64)	$t(65) = -2.09$, $p = .041$, $d = -0.89$
Yes	6	275.83 (19.83)	
In the past three years			
No	50	240.4 (40.39)	$W = 361.5$, $p = .36$, Rank-Biserial Corr. = -.15
Yes	17	244.35 (52.41)	
In the past five years			
No	38	242.13 (41.42)	$W = 536.5$, $p = .86$, Rank-Biserial Corr. = -.03
Yes	29	240.45 (46.5)	
Since first riding			
No	33	240.88 (42.17)	$W = 524$, $p = .65$, Rank-Biserial Corr. = -.07
Yes	34	241.91 (45.11)	
Since first riding (freq.)			
Never	33	240.88 (42.17)	$F(3, 67) = 2.09$, $p = .11$, $\omega^2 = 0.05$
Once	21	245.52 (34.19)	
Twice	9	255 (40.18)	
> twice	4	193.5 (80.95)	

Significant differences in response inhibition were found only based on self-reported crashes in the past year. The group that reported having experienced a crash showed poorer response inhibition than the group that reported no crashes. Response inhibition is crucial in situations requiring drivers to react quickly, such as adjusting their driving behavior, stopping an ongoing action, or shifting from ‘automatic driving’ mode to regain control [34]. In hazardous situations, response inhibition helps prevent impulsive responses, such as continuing to drive at high speeds or changing lanes without first ensuring that the lane is clear. Thus, good response inhibition can prevent drivers from collisions [11].

However, there is an important caveat regarding this finding. Since traffic accidents are relatively rare, there is a significant difference in the sample sizes between the two groups. This difference in group sizes may have influenced the statistical results. Therefore, although the effect size is large ($d = 0.89$), caution is needed when interpreting these results.

The findings also showed no significant differences in response inhibition based on crash involvement in the past three years, the past five years, or since the first motorcycle riding. However, it is important to note that this study relied on self-reported crashes. While self-reported crashes offer several advantages and can complement accident data [35], this method has limitations, such as potential memory issues [36]. Events occurring more than a year ago are particularly susceptible to recall bias. In addition, the assessment of response inhibition at a single time point may be less relevant for understanding long-term driving performance, given its developmental nature.

Therefore, we recommend exploring the effects of response inhibition using more objective driving performance measures to draw more robust conclusions about its impacts. We also encourage researchers to replicate this study by examining differences in response inhibition based on self-reported crashes in the past year, ensuring a relatively balanced sample size between groups.

This study also identified the phenomenon of underage riding, with participants reporting that they began riding motorcycles at an average age of 14.6 years. This finding is consistent with previous studies indicating high rates of underage riding in Indonesia [37], [38]. Meanwhile, response inhibition continues to mature during adolescence [2], [8], [21]. Given the observed association between response inhibition and self-reported crash involvement, the results suggest the importance of strengthening the implementation of minimum age regulations for motorcycle riding. Effective implementation requires collaboration among the government, parents, and schools.

Apart from that, this study has limitations. As noted by Poulton et al. [25], response inhibition performance may be affected by fatigue. Some cadets appeared to experience fatigue and mild coughing while completing stop-signal tasks. Even though the number was only small, this condition may affect the overall results.

Conclusion

This study revealed differences in response inhibition between groups that had experienced a crash and those that had not in the past year. Participants who reported no crash in the past year demonstrated better response inhibition than those who reported being involved in a crash. However, these differences were not observed over longer durations, such as three years, five years, or since the first motorcycle riding. While these findings support the relationship between response inhibition and driving performance, further studies are needed to confirm them using more objective driving performance measures or balanced sample sizes between groups.

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