Journal of Fundamentals of Mental Health

Mashhad University of Medical Sciences

Psychiatry and Behavioral Sciences Research Center

Original Article **Open Access**

The role of cognitive interference in reaction time: Insights from Go/No-Go and Flanker tasks

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Abstract

Introduction: A key characteristic of human information processing is goal orientation, which allows us to focus on specific aspects of a current stimulus while ignoring others based on our cognitive goals. Previous studies have shown that Reaction Time (RT) can be influenced by interference. This study aims to investigate this effect using the Flanker paradigm and explain how different interference types impact RT and accuracy. Also, this study examined RT for correct and incorrect responses.

Materials and Methods: This study was conducted on 110 female students from schools in Mashhad City, Iran, during the 2022-2023 academic year. Participants performed both the Go/No-Go task (which lacks interference) and the Flanker task (which involves four types of interference). The researcher analyzed the mean RT for both tasks, the impact of interference on RT and accuracy, and the RT for correct and incorrect responses.

Results: Findings confirmed that interference in the Flanker task affects RT. It has been found that incongruent interference significantly impacts both accuracy and RT ($P< 0.05$), and incorrect responses were slower than correct ones, likely due to delays as the brain reassesses and experiences conflict about the correct response.

Conclusion: The study demonstrates that both the presence and type of interference affect reaction time and accuracy, with reaction time being longer for incorrect responses.

Keywords: Attention, Cognition, Inhibitory control, Interference, Reaction time

Please cite this paper as:
Sahaf SMS. The role of cognitive interference in reaction time: Insights from Go/No-Go and Flanker tasks. Journal of Fundamentals of Mental Health 2025 Mar-Apr; 27(2):93-99. DOI: 10.22038/JFMH.2025.81847.3154

Introduction

A key characteristic of human information processing is goal orientation, which enables us to focus on specific aspects of the current stimulus while ignoring others, depending on the cognitive goal of the moment (1). Despite this remarkable inhibition, shifts in the contents of human thought occur rapidly and are typically uneventful, forming a routine part of daily life (2,3). However, issues arise when efforts to regulate thought content disrupt goal- or task-oriented information processing (4). It has been shown that the inability to control mental content and suppress task-irrelevant thoughts becomes particularly problematic for cognitive functioning (3). Research indicates that

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Received: Aug. 18, 2024
Accepted: Dec. 30, 2024

cognitive inhibition is crucial in various psychiatric disorders, including schizophrenia, obsessive-compulsive disorder (OCD) (5), Post-Traumatic Stress Disorder (PTSD) (6), and Attention -Deficit/ Hyperactivity Disorder (ADHD) (7).

Furthermore, in children, the ability to resist distraction is considered an important prerequisite for successfully acquiring academic competency (8,9). This suggestion is related to various factors, such as visual working memory (10) and shifting (11). Therefore, it is concluded that distraction can reduce the probability of a correct response. Reaction Time (RT) is the interval between stimulus presentation and the initiation of a voluntary response, encompassing various forms of stimuli, such as visual and auditory inputs (12). RT can be classified into three types: 1. Simple RT: Involves a single stimulus and a single response. 2. Recognition RT: Involves distinguishing between stimuli that require a response and those that do not, and 3. Choice RT: Involves multiple stimuli and possible responses, where the participant must select the correct response based on the specific stimulus (13). In response to a situation, RT can significantly impact our lives due to its practical implications (14). Factors affecting the average human RT include age, sex, handedness (left or right), fatigue, environmental conditions, and distractions (15,16).

In addition to causing less accurate performance, distraction can also cause slower response times (17,18). Distractions cause individuals to take longer to process information and react, highlighting the detrimental impact of irrelevant stimuli on cognitive efficiency (17).

Current models of cognitive control assume that the human processing system is sensitive to the consequences of processing irrelevant stimulus information (19). Consistent with this idea, interference reductions under increased frequency of compatible trials and/or reduced frequency of incompatible trials have been found in various interference paradigms, including the Flanker and Stroop task (20). These tasks have shown that an increased frequency of distractions can influence RT (21). However, the research findings were inconsistent (22,23). For instance, a study that manipulated the ratio of compatible to incompatible Stroop stimuli found that Stroop interference was affected by these changes (24). Alongside these inconsistencies, the varying effects of different types of interference, and the need to explore this topic in children, investigating the factors associated with cognitive interference can enhance our understanding of developmental processes and daily functioning. In this context, the study explores cognitive interference and its impact on RT and accuracy, specifically through a comparative analysis. Unlike previous research, it examines how different types of interference affect correct and incorrect responses, offering fresh insights into attentional and inhibitory control mechanisms. Additionally, the dual-task approach provides a deeper understanding of the effects of interference on RT and accuracy. To address these issues, the researcher considers three questions: 1) Does interference affect RT in comparing Flanker and Go/No-Go tasks? 2) Does the type of interference influence RT and the accuracy of responses? 3) What are the differences between RTs for correct and incorrect responses?

Materials and Methods

The study population consisted of 115 girls aged 9 to 11 years. Although this age group is younger than those typically used in experimental psychology studies, there is evidence that cognitive functions such as attention control have matured by this age (25). The children, all students, were selected from private schools in Mashhad through convenience sampling during the 2022-2023 academic year. Parents could receive more information and were invited to visit the school counseling center for further explanations.

The inclusion criteria included children enrolled in private schools in Mashhad during the 2022-2023 academic year, female students with no known cognitive, emotional, or behavioral disorders, as identified by school counselors and teachers. Parents provided written informed consent for participation in the study. The exclusion criteria included children with diagnosed intellectual disabilities or learning disorders, children diagnosed with ADHD, and students who received grades of "good" or "needs effort" in two or more subjects, as assessed by their school, were excluded. Based on Kinder et al. (26), we conducted a sample size calculation for our study using G*Power software. In the context of our planned MANOVA statistical test, the researcher used an effect size of 0.2, an alpha level of 0.05, a power of 0.95, and a correlation of 0.5 between measurements, with two measurements for each participant. The sample size calculation indicated that 84 participants would be sufficient to detect significant effects. However, to strengthen the reliability of our results and account for potential invalid data, we opted to include a larger sample size than the calculated minimum. This approach helped ensure more robust findings and reduced the impact of any incomplete or unusable data.

Research instruments

A) Flanker task: This task is widely used to assess attention, cognitive control, and the ability to manage interference from irrelevant stimuli. In this task, participants are presented with a central target stimulus flanked by distracting stimuli on either side. These stimuli can either be congruent, making the task easier, or incongruent, creating interference and increasing difficulty. Participants are instructed to focus on and respond to the central target as quickly and accurately as possible, ignoring the flanking stimuli. The task measures reaction time and accuracy, providing insights into selective attention, cognitive control, and processing speed. It is particularly useful in developmental studies to examine how these cognitive functions evolve in children, in clinical research to assess cognitive deficits in various neuropsychological disorders, and in studies of cognitive aging to understand changes in attention and control in older adults (27).

B) Go/ No-Go task: This task is a cognitive task to assess response inhibition and impulse control. In this task, participants are presented with a series of stimuli and instructed to respond quickly to certain "Go" stimuli by pressing a button while withholding their response to "No-Go" stimuli. The task measures the ability to control impulsive actions and differentiate between action and inaction based on the stimulus presented. Performance is evaluated through reaction and error rates, with slower reaction times and higher error rates on No-Go trials indicating difficulties in inhibitory control. The Go/No-Go task is commonly used in attention, executive function, and self-control research. It is valuable for studying developmental changes in children, the impact of various psychological and neurological conditions, and the effects of aging on cognitive control (27).

Procedure

The participants sat in front of a 24-inch monitor and a keyboard, with the monitor and chair height adjusted to match each student's height. The children then received the necessary instructions for performing the tasks. During the Go/No-Go task, they are instructed to press a button when a specific "Go" stimulus appears while withholding their response when a "No-Go" stimulus is shown. The task records the participant's accuracy, reaction time on "Go" trials, and the rate of incorrect responses (false alarms) during "No-Go" trials. In the Flanker task, a fixed white cross was first displayed to the participants for 500 milliseconds, immediately followed by a horizontal array of five white arrows of equal size spaced 800 milliseconds apart. The width of the array was 10.5 centimeters. The participants were instructed to focus on the central arrow and ignore the other four arrows on either side. They were required to press the left key (left Shift key) if the central arrow pointed left and the right key (right Shift key) if the central arrow pointed right. The surrounding arrows could appear in four different conditions: all pointing in the same direction as the target arrow (figure A, congruent), all pointing in the opposite direction (figure B, incongruent), no arrows at all (figure C, no-interference), or a line without arrows (figure D, neutral). Each participant completed approximately 50 trials of incongruent, congruent, neutral, and no-interference conditions. The number of left and right responses and the type of interference were not equal and were presented randomly.

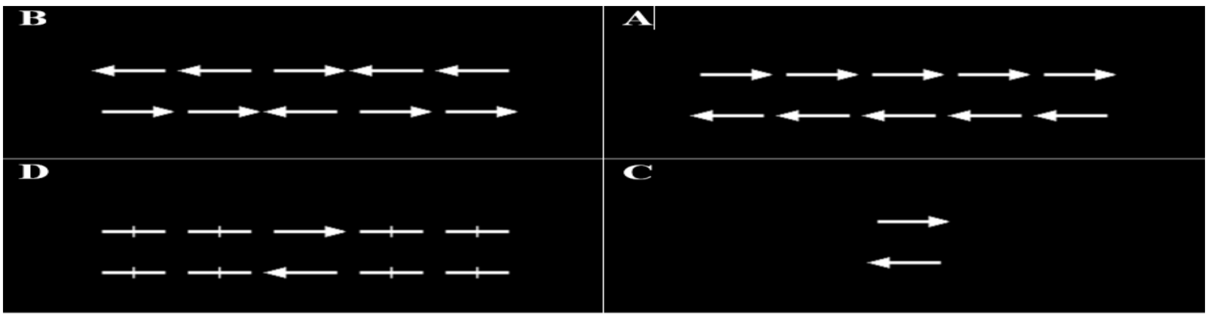

Figure 1. Characteristics of Flanker interference

The results were analyzed descriptively using the mean and standard deviation. The Kolmogorov-Smirnov test was used to assess the normality of the data distribution. To assess the differences in RT between the Go/No-Go task and the Flanker task, the researcher used an independent t-test. To examine the effects of interference type on RT and accuracy, we employed MANOVA, and to compare the differences in RT between correct and incorrect responses, we used an independent t-test. To further explore the MANOVA results, the Scheffé post-hoc test was applied.

Results

Due to difficulties in data collection and extraction, the information for 5 individuals was excluded, leaving 110 participants whose data were processed. The average age of the participants was 10.35 years (SD= 1.7). Additionally, all participants were female, and no intellectual, academic, or psychological issues were reported within the group.

Does interference affect RT in comparisons between Flanker and Go/No-Go tasks?

The researcher compared the mean difference in RT between the two tasks to address this question. As shown in Table 1, the mean difference between the two groups was significant. This indicates that interference significantly increased the reaction time under this condition.

Table 1. RT results in Flanker and Go/No-Go tasks

RT	Mean (SD)	Levene's Test	Sig.	Mean Difference	95% Confidence Interval of the Difference	
Go/No-Go	527.93 (5.72)	0.27	0.02	-19.63	-36.16	-3.11
Flanker	547.57 (12.23)					

Does the type of interference influence RT and the accuracy of responses?

To address this question, the researcher compared the mean of correct responses and RT across the four types of interference.

Since the data distribution was normal ($P > 0.05$), MANOVA was used to assess the significance of differences among the various conditions (Table 2).

Table 2. Correct responses and RT across four types of interference

	Sum of Squares	df	F	P
Correct	6.380	3	10.293	< 0.01
RT	602123.260	3	12.028	< 0.01

The results in Table 2 indicated significant differences in the number of correct responses and reaction times among the four conditions ($P < 0.05$).

To examine the significance more precisely, a post-hoc test was conducted. The results of the Scheffé post-hoc test are presented in Table 3.

Table 3. Scheffé post-hoc result for correct responses and RT

		Correct responses			RT		
		Mean Difference	95% Confidence Interval		Mean Difference	95% Confidence Interval	
incongruent	no-interference	-0.092*	-0.126	-.058	28.330*	18.637	38.023
	congruent	-0.073*	-0.107	-.040	18.675*	8.969	28.381
	neutral	-0.064*	-0.098	-.030	22.392*	12.697	32.088
no-interference	incongruent	0.092*	0.058	.126	-28.330*	-38.023	-18.637
	congruent	0.018	-0.015	.052	-9.655	-19.377	.066
	neutral	0.028	-0.005	.062	-5.937	-15.648	3.773
congruent	incongruent	0.073*	0.040	.107	-18.675*	-28.381	-8.969
	no-interference	-0.018	-0.052	.015	9.655	-.066	19.377
	neutral	0.009	-0.024	.043	3.717	-6.006	13.441
neutral	incongruent	0.064*	0.030	.098	-22.392*	-32.088	-12.697
	no-interference	-0.028	-0.062	.005	5.937	-3.773	15.648
	congruent	-0.009	-0.043	.024	-3.717	-13.441	6.006

*$P < 0.01$

What are the differences between RTs for correct and incorrect responses?

To answer this question, the researcher analyzed RTs for correct and incorrect responses. The descriptive report and t-test analysis can be found in Table 4.

Table 4. T-test result for RT in correct and incorrect responses

	N	RT mean (SD)	t	P	95% Confidence Interval	
Correct	3890	540.53 (113.62)	-4.002	< 0.01	-26.199	-8.969
Incorrect	1607	558.54 (161.22)				

Discussion

As results indicated, interference in the Flanker task affects RT. The data showed a significant increase in RT during the Flanker task, supporting the theory that increased interference leads to longer RT. The Go/No-Go task lacks interference, while the Flanker task involves four types of interference. The findings align with prior research demonstrating that distractions can increase RT. In a previous study, 100 children involved in musical education were administered the Stroop task, and significant interference effects were observed.

The study identified a Stroop-like effect and its reverse; however, these effects did not develop in parallel. This finding suggests that the interference effect does not correlate linearly with practice or skill development. The authors proposed that the strength of the interfering process plays a critical role in shaping these effects, emphasizing the importance of considering the dynamics of interference in cognitive tasks (20).

Furthermore, the researcher demonstrated that the type of interference can have varying effects on both RT and accuracy. The researcher examined four types of interference in the Flanker task and found significant differences in RT and accuracy. The results of the post-hoc test provided detailed insights into these differences. The researcher concluded that incongruent interference significantly differs from other types of interference in both accuracy and RT. Although previous studies have demonstrated that irrelevant stimuli can reduce accuracy and correct responses, the specific impact of different types of interference has yet to be thoroughly explored (20,22,28).

While the impact of interference on RT and accuracy is inconsistent, it may be contingent on the specific type of interference encountered. This notion is supported by the study by Consiglio et al., who investigated the influence of phone conversations and other potential distractions on RT in a braking task. Their study utilized a laboratory setup designed to replicate the foot movements involved in driving. A total of 22 participants were instructed to release the accelerator pedal and press the brake pedal as swiftly as possible upon detecting the activation of a red brake light. The mean RT was assessed across different experimental conditions. The results demonstrated that engaging in conversation, whether in-person or via a mobile phone, led to increased RT, whereas listening to music on the radio had no significant interference effect (29). The findings showed that not all types of interference impact RT and accuracy, but the most challenging interference in the Flanker task does produce significant differences. Therefore, within this paradigm, studies should emphasize the accuracy and complexity of interfering stimuli.

Finally, the researcher compared the mean RT for both correct and incorrect responses. We found a significant difference between the RTs, with incorrect responses being slower than correct ones. This indicates that children take longer to respond when their response is incorrect. This finding aligns with previous research. For example, Frej conducted a study with 231 pedestrians, demonstrating that individuals frequently use mobile phones while crossing at pedestrian crosswalks. Their findings indicated that pedestrians engaged with mobile phones tend to walk at a slower pace and exhibit reduced awareness of oncoming vehicles, often crossing without caution or checking their surroundings (30).

Furthermore, mobile phone users at crosswalks are less attentive to traffic signals, instead relying on the movement of nearby pedestrians. Additionally, the study by Files (31) demonstrated that incorrect response reaction times are slower than correct responses in an EEG paradigm. This can be explained by research indicating that the brain often detects potential errors while forming a response (32). This error detection can cause a delay as the brain reassesses or second-guesses the initial response, resulting in slower reaction times even if the response remains incorrect (33,34). Also, when individuals encounter a situation where they are uncertain or conflicted about the correct response, cognitive processing may slow down.

This internal conflict can lead to hesitation, resulting in a longer RT before responding incorrectly. Dubravac et al. investigated this phenomenon in a study involving 140 participants aged 9 to 13 years, using the Simon task to examine RT across four trials. Both children and adults exhibited a decrease in RT following interference. Additionally, RTs were disproportionately high on the first post-error trial, followed by a gradual decline in slowing. The findings indicated RT decreased after interference, with children slowing more than adults (35). Generally, previous studies have reported inconsistent findings. This study provides a unique examination of the role of interference by comparing the Flanker and Go/No-Go tasks and evaluating the type of interference within each task, offering a novel approach to the topic. This study had limitations, including using only female students and relying on convenience sampling. Future research should refine task parameters and include more diverse samples to understand the effects of interference better.

Conclusion

This study demonstrates that both the presence and type of interference influence RT and accuracy, with incongruent interference having the most significant impact. This finding supports previous research linking distractions to increased RT and highlights the need for future studies to examine the types and difficulty of interference more closely. We also concluded that RT for incorrect responses is longer, possibly related to delays as the brain reassesses and experiences conflict about the correct response.

Acknowledgments

The author thanks all the participants and schools that participated in this study.

Conflict of Interests

The author declares no conflict of interest.

Funding

The author declares no financial support.

Ethical Considerations

The study was conducted in schools with voluntary participation and informed consent. All data were anonymized to ensure privacy, and no identifying information was disclosed or shared publicly. The Neuroscience Research Center, Mashhad University of Medical Sciences, oversaw data processing and result reporting.

Authors' Contributions

The author involved in all aspects of this research, including study design, data collection, analysis, and manuscript preparation.

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