P2465 Attention Reading Review

Reference: Logan, G.D. & Cowan, W.B. (1984). On the ability to inhibit thought and action: A theory of an act of control. Psychological Review, 91, 295-327.
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Date: 11/11/2008 **FileName:** 46_Logan_ThoughInhibition_outline.doc

Introduction:

The gist:
This article addresses studies of motor control and cognitive control within framework of combining an *executive system* for intention and commands and a *subordinate system* for interpretation and execution.

The specific act of control they focus on is inhibition of thoughts and actions that are no longer relevant to current goals, which is important for both cognitive and motor control.

Three specific issues are addressed in this article within both domains:
1. Measuring the difficulty of control
2. Measuring the latency of control
3. Measuring the ballistic component of the process being controlled. – define ballistic components as parts of a process that cannot be inhibited and must be completed before they can stop.

Bottom line:
To propose the theory, predictions and methodologies of the *stop-signal procedure* as a way to study control.

Stop Signal Paradigm

What is the Stop-Signal Paradigm?
Subjects are asked to perform a certain task and intermittently given a cue telling them to *stop* responding on the upcoming trial.

Why study it?
1. Some are interested in the unique refractory response to stop a task compared to other types of signals.
2. Some want to learn about catch-trials in RT tasks
3. Some are just interested in stopping itself.
4. No actual general theory of control processes that stop-signals require.

Purpose:
1. Want to study the *probability* of inhibiting a response to the primary task (Inhibition function).

2. Want to study the latency of responses with no stop-signal compared to latency of escaped inhibition and latency of internal response to the stop signal (Primary task reaction time and signal respond reaction time).
3. Present an empirical study and then a model to help explain the paradigm.

Empirical Study

6 one hour sessions per subject (N=3).
Extensive practice with stopping prior.

Method:

1. Classifying single letters drawn from a set of four. 2 letters assigned to one response and two assigned to another response.
2. 800 trials → each letter presented 200 times.
3. Fixation point (500 ms) → Letter (500 ms) → 2s ITI.
4. Stop signal was a 500ms 900hz tone at one of 10 delays (50ms intervals from 0-500) after letter onset. Occurred 25% of the time (200 trials per session → 20 times per delay per session → 5 times per letter per delay per session).
5. Randomized order of letter, stop signals and delay.
6. Subjs responded by pressing one of two keys.

Results and Discussion:

Inhibition function

Consistent with the literature, probability of responding given a stop signal systematically increased with delay of stop-signal.

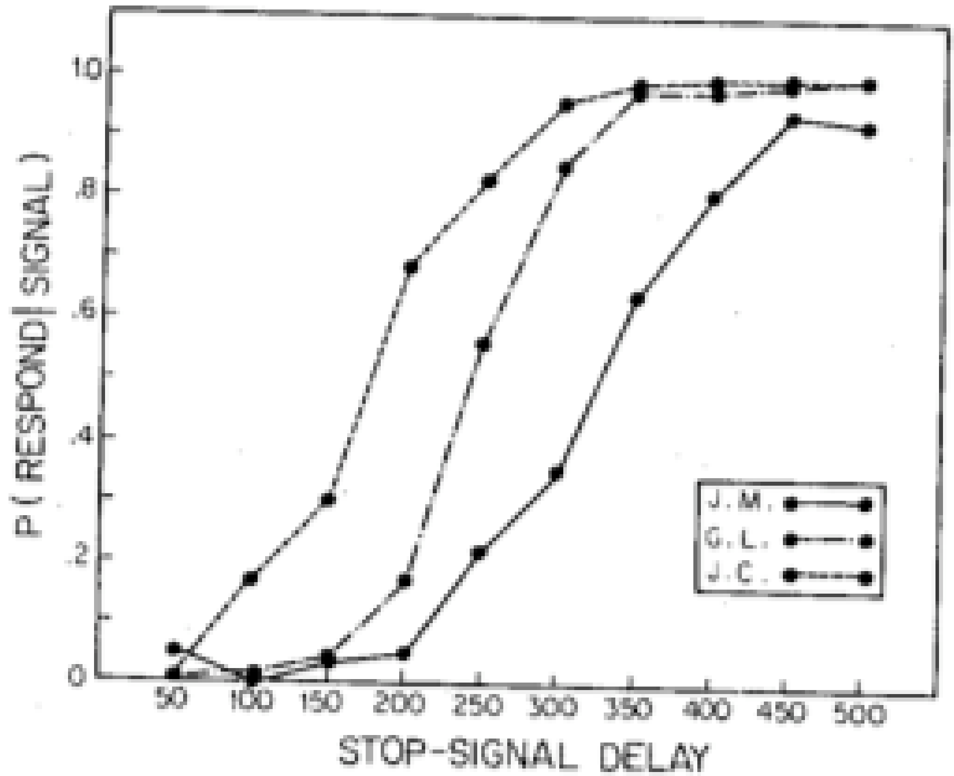


Figure 1. The probability of responding given a stop signal—*P*(respond|signal)—as a function of stop-signal delay for subjects J. M., G. L., and J. C.

Primary-task reaction time

Table 1
Mean Reaction Time, Standard Deviation, and Proportion of Errors From Trials on Which No Stop Signal Occurred

	Subject		
Measure	J. M.	G. L.	J. C.
Mean RT	482	452	378
SD of RT	110	50	58
P (error)	.01	.04	.02

Reaction time to task in trials with no stop signal indicated that subjects who had *faster RTs* had higher probabilities of responding during trials that had stop-signals. (Also consistent with the literature).

Signal-respond reaction time

Table 2

Mean Reaction Times From Trials on Which Stop Signal Occurred but the Subject Responded (Signal-Respond Trials)

	Stop-signal delay										
Condition	50	100	150	200	250	300	350	400	450	500	Mean
					J. M.						
Observed	617	—	365	356	371	397	415	444	441	455	434
Predicted	315	—	305	315	361	382	420	442	464	461	434
					G. L.						
Observed	391	438	428	378	423	447	440	457	454	451	445
Predicted	312	325	340	378	418	438	449	449	450	452	441
					J. C.						
Observed	337	351	362	349	372	384	375	371	380	390	374
Predicted	293	302	315	347	359	372	376	378	378	378	366

Note. Mean = mean weighted by frequency of occurrence.

On trials where stop-signal occurred but subjects responded anyway showed a decrease in RT in stop-signal trials compared to no signal trials and these RTs increased with stop-signal delay.

Bottom line:

1. Results were consistent with previous findings
2. All effects found were also later accounted for by the model
3. This is as far as they could go empirically and relied on the model to guide further interpretation.

<u>The Horse Race Model</u>

1. The model – generates a response for the primary task and the stop-signal and executes a "race" between them. If the primary task process is first, the task is executed, if the stop-signal process finishes first, the task is inhibited.

2. Finishing times are assumed to be independent random variables.

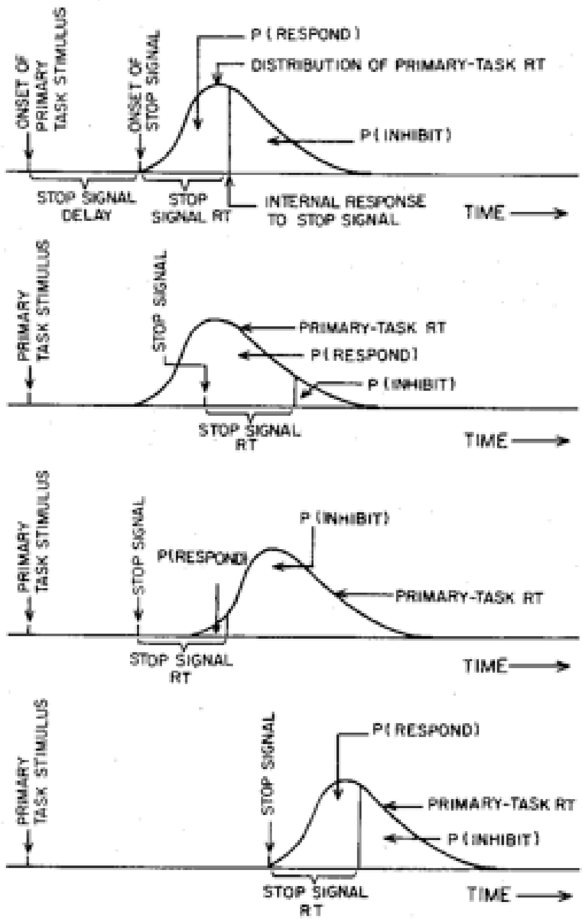
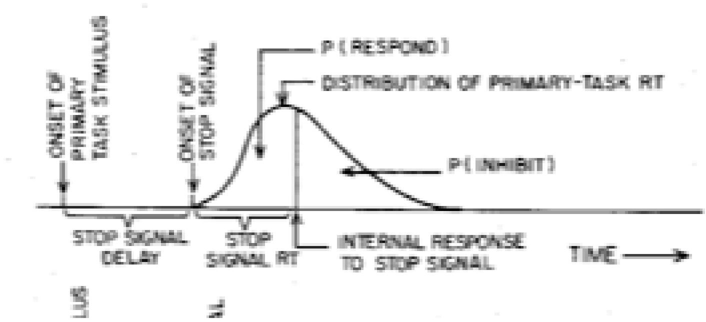


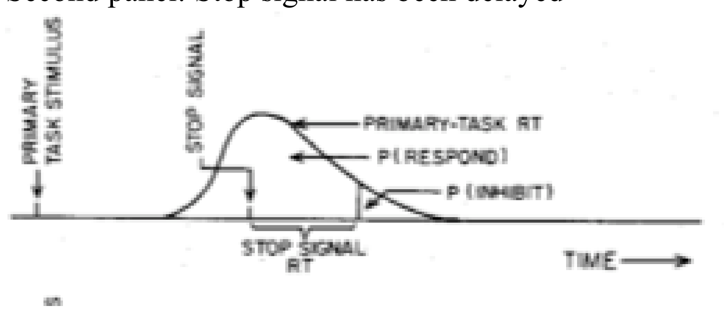
Figure 2. Graphic representation of the assumptions and predictions of the horse-race model, indicating how the probability of inhibiting a response—*P*(inhibit)—and the probability of responding given a stop signal—*P*(respond)—depend on the distribution of primary-task reaction times, stop-signal reaction time, and stop-signal delay.

4. Top panel: Assumes that response to the stop signal is constant and no "ballistic" phase.
   Vertical line represents the point at which the stop signal occurs.
   Left side of line – response to the primary task is faster than response to stop signal and the probability of responding to the primary task given a stop signal.
   Right side of line – response to the stop signal is faster than response to the primary task and the probability of inhibition.



Inhibition functions

1. Second panel: Stop signal has been delayed



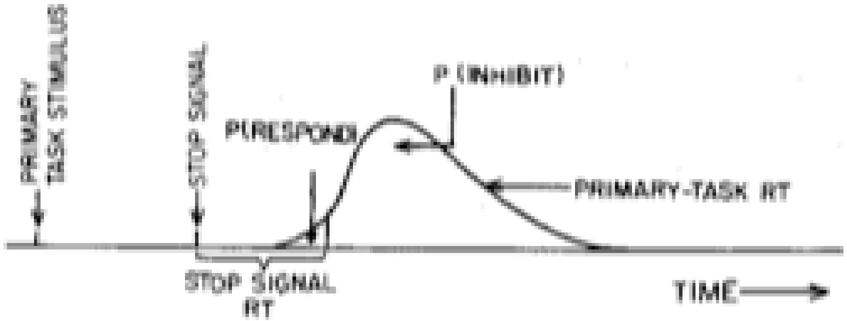
2. Reduces the probability of inhibition and increases probability of response given a signal.

$$P_r(t_d) = \int_{t_s + t_d} f(t)dt$$

3. $P_r(t_d)$ is the probability of responding during a signal-trial (signal-respond)
4. ts is the duration of the stop signal process
5. td is the delay of the stop signal (constant)
6. f(t) is the RT distribution of no-signal trials
7. The unknown in the equation is ts, the other values are manipulated (td) or observed

Primary-Task Reaction Time

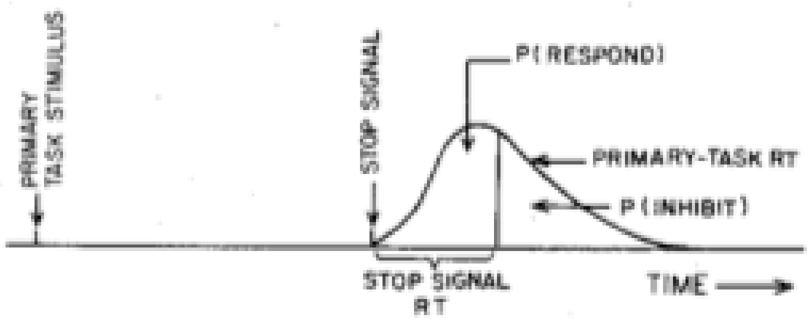
1. Model accounts for effects of primary-task reaction time in terms of biasing relative finishing times of the stopping process and response-generation process.



2. Primary-task RT is delayed relative to the top panel, increasing probability of inhibition and decreasing the probability of responding given a stop-signal.

Signal-Respond RT

1. Predicts that signal-respond RTs will be faster than no-signal RTs and increase as a function of stop-signal delay.



2. Mean signal respond RT represents the mean of the portion of the primary-task RT distribution and represents the internal response to the stop signal. It is only the area behind the stop signal line. The primary task RT for no-signal means include the whole distribution and therefore those RTs will be faster because they exclude the longer tail of the distribution.
3. Increase in signal RT with delay occurs because the internal response to the signal cuts off more of the primary task RT distribution as delay increases.

4. Predictions were made in the model for each subject. Discrepancies were small.

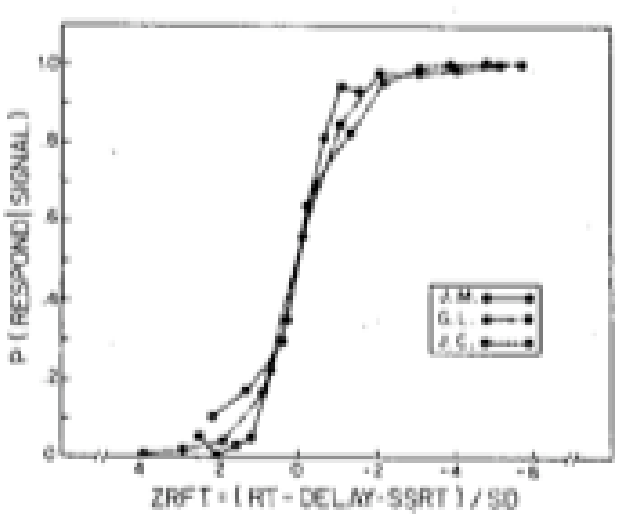
Stop –Signal Reaction Time

1. Estimate reaction-time of the internal response to the stop signal at a given delay.
2. Integrate no-signal reaction time distribution until it equals the probability of responding given a stop signal.
3. Results showed no interference between the stopping process and the primary-task process consistent with the notion that the stopping process and primary-task process are independent.

4. Estimated stop signal RT decreases as stop-signal delay increases which may be a consequence of variability in stop-signal RT.

Inhibition functions and Primary-Task Reaction Time

1. Response to stop signal depends on four factors
    a. Stopping signal delay (t_d)
    b. Stop-signal RT (t_s)
    c. Mean and standard deviation of the primary-task RT which can be expressed as a Z-score.



2. Show differences in inhibition functions due to variation in parameters of the primary-task reaction time distribution by plotting the probability of responding given a signal.
3. Differences were minimal.
4. Model suggests this is the bet way to account for differences in variable because it represents relative-finishing time.
5. Important because if different inhibition functions can be brought into alignment, can conclude that the same control process applies to them. And different conditions are equally difficult to control.

Independence of process

1. No signal and stop signal reaction times should not be and are not different from single-task controls which was shown in the empirical data.
2. Signal-respond RTs should be faster than no-signal RTs and these increase with stop-signal delay.
3. Both predictions have been confirmed.

4. Paper goes through and disproves alternative possibilities indicating a sharing of resources.

Overview

1. When stopping time and ballistic process are included as random variables, formal model becomes more complex.
2. Probability of inhibition, no-signal RT and stop-signal RT all depend on stop signal delay.
3. If stop signal occurs early enough, no response
4. If stop signal occurs late enough, always a response.
5. Later a stop signal occurs, increased probability of a response.

General Discussion

Measuring difficulty of control

1. Compare inhibition functions and attempt to remove differences by plotting them as a function of some transformation of delay that takes into account difference in the mean and variance of primary task RT and differences in stop-signal RT. Functions that cannot be aligned must involve different control processes and may have a ballistic component.
2. IF alignment occurs: compare parameters of the model. Stop-signal RT is critical. Larger stop signal RTs are harder to control. But empirical studies show that performance is usually controlled pretty closely
3. Estimates of latencies on different studies show that motor control, RT, higher cognitive processes all yield estimates of around 200ms.
4. This corroborates with the analysis of inhibition functions suggesting that subjects typically have very close control over actions.

Measuring the latency of control

1. Estimates of stop-signal RT provide a measure of latency of control.
2. This can be established in two ways:
    a. Calculated from the probability of inhibition and primary-task RT distribution
    b. Calculated from the mean of the inhibition function and the mean of primary-task RT.
3. Can use both methods

Measuring the ballistic component of the process being controlled

1. If a component of a task must run to completion before stopping, stop signals presented before will not be effective → Probability of inhibiting responses based on the component should be zero.

2. Flat inhibition functions suggest the presence of a lengthy ballistic component.
3. Similar to predictions for the psychological refractory period made by single-channel theory.
4. Shown in typists (couldn't stop typing over typed words).
5. Speech can also be ballistic

Expanding the focus of the model

1. So far only address discrete tasks with discrete responses. But can be applied to continuous responses by imposing discrete criteria on the continuous task.
2. Interesting to study continuous responses because they offer a way of estimating stop-signal RT independent on inhibition functions. Time between onset of the stop signal and occurrence of last response can be used as an estimate of stop-signal RT.
3. Can be applied to thought processes as well as action processes → as thoughts also sometimes need to be inhibited.
4. However, thoughts are generally not observable.
5. Studies that make thoughts observable set a task in which some response is made contingent on thought → but difficult in the stop-signal paradigm as only the inhibition of response can be measured.
6. Logan (1983) → Presented subjects with pairs of words and make category and rhyme judgments. Occasionally presented a stop-signal telling them to inhibit their response to the pair. Tested their ability to recognize inhibited words. If thoughts were inhibited, memory should be worse but increase as a function of stop-signal delay. Results showed that thoughts went on even after stop signal.

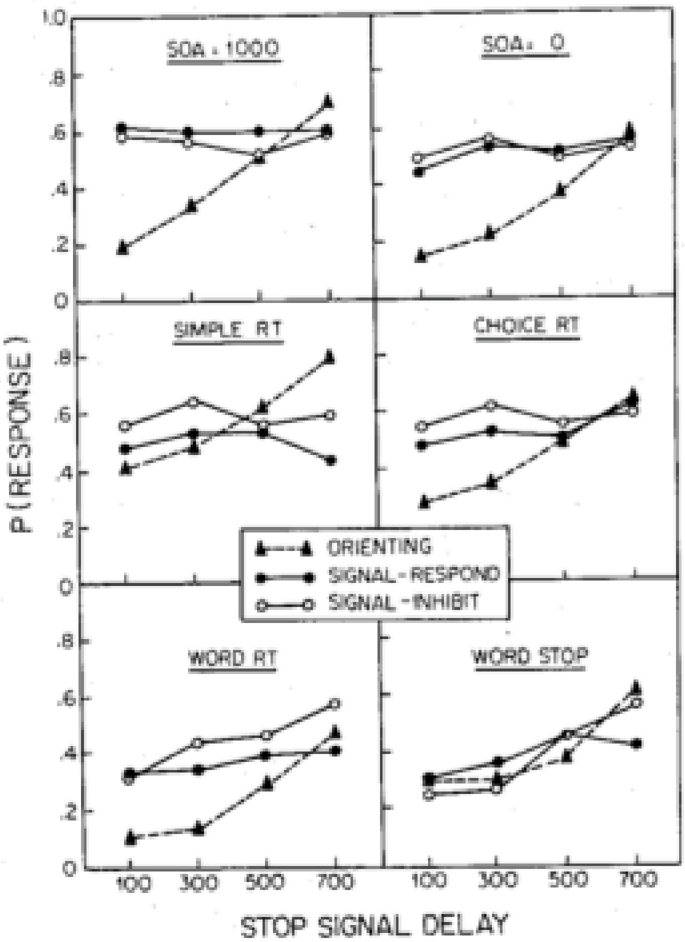


Figure 8. Inhibition functions for thought and action plotted against stop-signal delay. (Orienting = probability of responding given a stop signal in the orienting task; signal-respond = probability of recognizing a word from the orienting task that occurred with a stop signal and received a response; signal-inhibit = probability of recognizing a word from the orienting task that occurred with a stop signal and did not receive a response. From "On the Ability to Inhibit Simple Thoughts and Actions: I. Stop-Signal Studies of Decision and Memory" by G. D. Logan, *Journal of Experimental Psychology: Learning, Memory and Cognition*, 1983, 9, 585–606, Figure C1. Copyright 1983 by the American Psychological Association, Inc. Reprinted by permission.)

7. The only way to inhibit thought was to replace the word pair with another when the stop signal occurred. Memory performance improved as delay increased. Suggested that it was a change in display that inhibited thought ad NOT the stop signal.
8. Zbrodoff et al (1984) → Thoughts underlying arithmetic problems can be inhibited by interrupting actions associated with them. Perhaps because arithmetic is not as well practiced as word judgments and therefore less automatic.
9. Results suggest that horse-race models can be extended to processes that are not directly observable → still premature.

<u>Broader Implications</u>

1. Application of the horse-race model to the stop-signal paradigm and others suggests that subjects have very close control over actions. (stop action with 200ms).
2. Analysis of inhibition function showed that subjects can stop a response up to the point of execution and probability of inhibition depends on relative finishing times of the stopping task and primary task,

Attentional control

1. Consistent with a *late-selection* theory of attention.
2. Theory proposes that attention has its selective, controlling influence at later stages of processing, after stimuli have had complete access to the semantic system.
3. Late locus of control would account for the short ballistic component observed in stop-signal studies. Also account for the fact that the response inhibition depends on relative finishing time rather than starting time; control is exerted at the point that stimulus information reaches the motor system, regardless of how long it took to get there.
4. Facts are also consistent with a hierarchical theory of attention → attention has its selective controlling influence by acting as an executive that gives orders to subordinate systems → subordinate systems carry out the orders till countermanded by the executive.
5. Hierarchical theory (attention is an executive w/ subordinates) is consistent with double-stimulation paradigms (one cue, multiple associations) since its prioritizing system (executive) is separate from its signal processing system (subordinate).

Automaticity and Control

1. Modern theories suggest that that automatic and controlled processes are opposites. Automatic responses cannot be inhibited whereas control processes can.
2. Stop signal studies show that highly skilled and "automatic" actions (typing, speaking) are actually controlled very closely. And according to he model and empirical evidence, the time required to stop pretty automatic actions is the same

as time required to stop simpler actions.

3. Automatic actions are controlled to a certain extent even if errors of attention occur, they are usually small substitution in detail. Automatic processes are controlled insofar as they are engaged to bring about a goal. All goal directed activity is controlled regardless of whether its executed by executive or subordinate.
4. Paper suggests new direction for research on automaticity → find out what aspects of the subject's interaction with the environment are being controlled and what the subject does to bring about control. Then determine the roles of the executive and subordinate.
5. Role of inhibition is clearer in motor skills than in cognitive skills.