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Additive factors analysis of inhibitory processing in the stop-signal paradigm

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Abstract

This article reports an additive factors analysis of choice reaction and selective stop processes manipulated in a stop-signal paradigm. Three experiments were performed in which stimulus discriminability (SD) and stimulus-response compatibility (SRC) were manipulated in a factorial fashion. In each experiment, the effects of SD and SRC were assessed first for going and next for stopping. Two experiments yielded the anticipated additive relation between SD and SRC for going but stopping appeared to be insensitive to the SD manipulation. Increasing the SD demands in the third experiment by using a different display resulted in a significant (over-additive) interaction between SD and SRC for going and a non-significant (under-additive) interaction for stopping. The pattern of results that emerged from this set of experiments was interpreted to suggest that going and stopping are both similar and different. They are similar in that distinct stages can be identified in both going and stopping but they are also different, as selective stopping seems to be less sensitive to discrimination manipulations relative to going.

Keywords: Inhibition; Stop-signal paradigm; Additive factors method; Signal-response compatibility; Reaction time

1. Introduction

The ability to withhold and interrupt ongoing or planned actions in response to sudden changes in the environment is important for cognitive ('executive') control and is a prerequisite for adaptive and goal-directed behavior. Since the formalization of the *stop-signal paradigm*, about two decades ago by Logan and Cowan (1984), many researchers operating in various theoretical frameworks have adopted the stop task as an experimental tool to investigate inhibitory motor control (see Logan, 1994 for a review). In the stop task, participants perform a go task, usually a speeded choice reaction task requiring the binary choice discrimination of two visual signals by manually pressing one of two response buttons. Shortly after the onset of the go signal, participants are presented occasionally with a stop signal (usually a tone) that instructs them to withhold the response. The interval between the onset of the go signal and the presentation of the stop signal (or stop-signal delay) is under experimental control, enabling the experimenter to manipulate the probability of successful response inhibition on a given stop trial. Stopping is easy when the stop signal is presented early, but difficult or virtually impossible when it is presented late vis-à-vis the respond signal (e.g., Lappin & Eriksen, 1966; Logan, 1994; Logan & Cowan, 1984).

1.1. Studies using the stop-signal paradigm

Logan and colleagues have conceptualized performance on the stop-signal paradigm in terms of a horse

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race between go processes and stop processes. The go processes are initiated by the onset of the go signal, whereas the onset of the stop signal starts the stopping processes. Whether or not the go response will occur depends on the outcome of the race. If the go process wins, a response is produced despite the presence of a stop signal. Conversely, the response is successfully inhibited when the stopping process wins the race. One of the virtues of the horse-race model is that, with a small set of formal assumptions, it provides a method to estimate the stop latency, or stop-signal reaction time (SSRT) as an internal inhibitory response to the stop signal. Several reports in the stop literature indicate that SSRT appears to be rather invariant across tasks and typically amounts to values between 200 and 250 ms for healthy young adults (see Logan, 1994 for a review). Several response modalities have been investigated, including manual responses (e.g., Logan, 1981), speech utterances (Ladefoged, Silverstein, & Papcun, 1973), typing (Logan, 1982; Long, 1976; Rabbitt, 1978), foot movements (de Jong, Coles, & Logan, 1995), and eye movements (Hanes & Carpenter, 1999; Logan & Irwin, 2000). Somewhat prolonged stop latencies are reported for children (Bedard et al., 2002; Ridderinkhof, Band, & Logan, 1999; van den Wildenberg & van der Molen, 2004) and older adults (Christ, White, Mandernach, & Keys, 2001; Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Williams, Ponesse, Schachar, Logan, & Tannock, 1999).

In clinical settings, the stop-signal paradigm has been used successfully to distinguish between normal children and children diagnosed with attention deficit hyperactivity disorder (ADHD; Schachar & Logan, 1990). ADHD children exhibit less efficient stopping than children diagnosed otherwise and healthy controls (Jennings, van der Molen, Pelham, Brock, & Hoza, 1997; Oosterlaan, Logan, & Sergeant, 1998; Oosterlaan & Sergeant, 1995; Overtoom et al., 2002; Schachar & Logan, 1990; Schachar, Motta, Logan, Tannock, & Klim, 2000; van der Schoot, Licht, Horsley, & Sergeant, 2000; for a review of ADHD studies using the stop-signal paradigm, see Nigg, 2001). Stop latencies improved after administration of the stimulant drug methylphenidate compared with administration of a placebo in children with ADHD (Tannock, Schachar, Carr, Chajczyk, & Logan, 1989). Others studies reported negative effects of alcohol on stop latency within the normal population (Mulvihill, Skilling, & Vogel-Sprott, 1997).

1.2. The nature of stopping

Because of its generality, the horse-race model usually fits behavioral data obtained in the stop-signal paradigm very well. However, it does not provide a deeper understanding of the nature of the stopping process. Research aimed at determining the nature of the stopping processes itself can broadly be divided into three perspectives. First, several studies focused on the interaction of stopping with other forms of inhibition. A second approach involves complicating the standard stop paradigm. Finally, psychophysiological and brain imaging studies extended our understanding of the neural substrates that underlie motor inhibition in the stop-signal paradigm.

The first strategy to investigate the nature of stop processes focuses on stopping in relation to other forms of inhibition. Several investigators crossed stopping with experimental manipulations that draw upon some other form of inhibitory control. An interaction between the two stopping varieties is then taken to suggest that they share a common mechanism. Logan (1981), for example, observed that stop latency is approximately equal for spatially compatible and incompatible manual responses (see also Logan & Irwin, 2000). Apparently, stopping does not interact with the ability to resolve the conflict between the prepotent compatible response and the spatially incompatible response (see also van den Wildenberg & van der Molen, 2004). Others crossed stopping with the inhibition of responses to target stimuli flanked by task-irrelevant distracters assigned to the same or to the opposite response (Kramer et al., 1994; Ridderinkhof et al., 1999). These investigators found that responses to targets flanked by incongruent distracters were more difficult to inhibit than responses to congruent displays. This pattern of results was interpreted to suggest that stopping and the need to inhibit the (incorrect) response to incongruent flankers compete for execution (cf. Ridderinkhof et al., 1999; Verbruggen, Liefooghe, & Vandierendonck, 2004). Finally, stop-signal inhibition has been crossed with response readiness (van den Wildenberg, van der Molen, & Logan, 2002). Subjects performed a primary task requiring a speeded binary choice reaction on go trials and response inhibition on nogo trials. An occasional cue informed subjects that a nogo trial was imminent but left them uncertain about the number of go trials separating the cue and the upcoming nogo trial. When subjects were anticipating a nogo signal, stopping was delayed compared to a control condition. This pattern of findings was interpreted with reference to a response readiness model suggested by Mattes, Ulrich, and Miller (1997; see also Ulrich, Mattes, & Miller, 1999).

Using the second strategy, other researchers examined stopping processes by complicating the stopping process (see Logan, 1994). For example, some investigators examined stopping in a change paradigm by asking subjects to stop one response and execute another (Logan & Burkell, 1986). It was observed that the duration of stopping is somewhat longer when it needs to be followed by the execution of another response than when it is not. Other investigators examined selective stopping by manipulation the validity of the stop signal (Bedard

et al., 2002; Riegler, 1986). Their subjects were presented with one of two stop tones – a valid stop signal, instructing the subject to stop the primary-task response, and an invalid stop signal requiring the subject to execute the go response as planned. These selective stop studies revealed that the duration of the stop process is lengthened when subjects have to stop their response to one of two stop signals but not to the other. Other studies of selective stopping asked subjects to inhibit only one response (e.g., the left hand) but not the other (e.g., the right hand) upon a stop signal. The results also showed that subjects are able to stop selectively (de Jong et al., 1995; Logan, Kantowitz, & Riegler, 1986).

The third strategy to assess the nature of stopping involves the use of psychophysiological measures of the dynamics of response activation and inhibition; that is, the lateralized readiness potential (LRP) in combination with the electromyographic (EMG) of the muscles involved in responding. The psychophysiological indices of response activation and inhibition led de Jong and colleagues to propose two separate inhibitory mechanisms – a slower central cortical mechanism capable of selective inhibition and a peripherally operating midbrain mechanism for fast non-selective or simple stopping (de Jong et al., 1995, 1990). The notion of a peripheral inhibition mechanism has been linked with results obtained from cardiac studies by Jennings, van der Molen, Brock, and Somsen (1992). These researchers reported that successful inhibition of a motor response is associated with heartbeat slowing (deceleration), whereas failed inhibitions were not. The fact that cardiac inhibition and motor inhibition interact has been interpreted to suggest that both are controlled in part by the same midbrain system. However, in their review of psychophysiological data in the stop-signal and related literature, Band and van Boxtel (1999) formulated an alternative interpretation of the neural mechanisms involved in stopping motor responses. Their main point was that a peripheral stop mechanism is incorrectly inferred from the psychophysiological data. Band and van Boxtel suggested an alternative model in which an integrated circuit of the prefrontal cortex and basal ganglia are candidate agents of response inhibition, whereas possible effect sites of inhibition are the thalamus and motor cortex (Brunia, 1993; Eimer, 1993; Goldberg, 1985; Jodo & Kayama, 1992; Kok, 1986; Naito & Matsumura, 1996; Pfefferbaum, Ford, Weller, & Kopell, 1985; van Boxtel, van der Molen, Jennings, & Brunia, 2001).

Brain imaging techniques (Pliszka, Liotti, & Woldorff, 2000; Rubia et al., 2001) and microelectrode studies (Kawashima et al., 1996; Sasaki & Gemba, 1986; Sasaki, Gemba, Nambu, & Matsuzaki, 1993) have provided support for the prefrontal substrate of inhibitory processing. Single-cell recordings in primates performing a stop task provide another psychophysiological window on the nature of inhibition. Hanes and colleagues recorded unit activity in the frontal eye fields during the countermanding of eye movements and identified single-cell signatures of inhibitory visuo-motor control (Hanes, Patterson, & Schall (1998); see Logan & Irwin (2000) for a behavioral study comparing inhibitory control of eye and hand movements).

1.3. The additive factors method

The goal of the current study was to assess component processes of inhibition in the stop-signal paradigm by adopting the theoretical framework of the additive factors method (AFM; Sanders, 1980; Sternberg, 1969). The AFM is a powerful tool for identifying components of the choice reaction process (Sternberg, 1969). Within this framework, choice RT is taken as the sum of durations of a set of sequentially ordered and independent processing stages. According to AFM logic, experimental manipulations that affect different processing stages have additive effects on mean RT. Conversely, an interaction is taken to suggest that the experimental manipulations affect at least one stage in common. In the AFM literature, it is well established that perceptual manipulations and response choice manipulations have additive affects on mean choice RT. Accordingly, perceptual manipulations and response choice manipulations are assumed to influence the rate of different processing stages (for reviews see Sanders, 1980, 1998; van der Molen, Bashore, Halliday, & Callaway, 1991).

The guiding of hypothesis of the present study assumes that stop processes are quite similar in nature to go processes. Go signals require perceptual analysis, translation into an appropriate action, and then the programming and unfolding of that action. Likewise, stop signals were assumed to require perceptual analysis, translation into an appropriate action (i.e., inhibition of ongoing responses), and then the programming and unfolding of that inhibitory action. The main purpose of the present study was to identify component processes or stages in the stop process using experimental manipulations that have been employed previously in the AFM literature to identify stages in the choice reaction process. In the AFM literature, it has been well established that perceptual and response choice manipulations exert additive effects on mean choice RT (for a review Sanders, 1998). These findings are based primarily on factorial combinations of stimulus quality (e.g., intact vs. degraded stimuli) and stimulus-response compatibility (SRC; e.g., a compatible SRC mapping requires a left-hand response to a left-positioned stimulus whereas an incompatible mapping requires a right-hand response to a left-positioned stimulus). The additive relation between these effects is interpreted to suggest that two distinct stages are involved – a *stimulus encoding stage* for feature extraction (influenced by stim-

ulus quality) and a *response selection stage* (influenced by SRC) for determining the correct response.

In the current study, SRC was used together with a task manipulation assumed to influence a stage in between stimulus encoding and response selection. A separate stage, labeled the *stimulus identification stage*, has been postulated on the basis of additive relations between the effects of stimulus quality, affecting the rate of the stimulus encoding stage, SRC, affecting response choice, and stimulus discriminability (SD). The latter manipulation refers to the degree of similarity between alternative stimuli and the stimulus identification stage is thought to represent the final selection from a set of possible stimulus alternatives (e.g., Frowein, 1981; Sanders, 1998; Stoffels, van der Molen, & Keuss, 1989). Although the evidence of a separate stimulus identification stage is still modest, Pluister and co-workers obtained a recurrent additive pattern between the effects of SD and SRC in a series of studies combining SD, SRC, and foreperiod (i.e., the interval between warning and imperative stimuli) (Molenaar, Dolan, & Pluister, 2004; Pluister, 2004). The SD and SRC manipulations were taken from Pluister and the research strategy consisted of two steps. First, SD and SRC were crossed to create four standard choice reaction tasks and, based on the results of Pluister, it was predicted that SD and SRC would produce additive effects on mean choice RT. Secondly, the same SD and SRC manipulations were used to create four selective stop tasks that were combined with a go task. Thus, the same signals that triggered the execution of a response in the standard choice RT tasks were employed as stop signals in selective stop tasks to prompt the inhibitory response. On the hypothesis that the nature of going and stopping processes are similar, it was predicted that SD and SRC manipulations would produce additive effects on selective stop-signal RT.

2. Experiment 1

SD and SRC were manipulated using the stimulus display of Pluister (2004), who presented subjects with a schematic face in which the position of the pupils served as the imperative stimulus. In the easy-to-discriminate condition, the pupils were positioned at an eccentric location relative to the center of the eyes and in the difficult-to-discriminate condition the pupils were positioned close to the center. SD was crossed with SRC. In the compatible condition, subjects were instructed to respond in the direction of the gaze (i.e., left-positioned pupils required a left-hand response) while in the incompatible condition, subjects were required to respond in the opposite direction (i.e., left-positioned pupils required a right-hand response). Given the findings reported by Pluister (2004), SD and SRC should produce additive effects on choice RT, suggesting that these manipulations alter the rate of two independent stages, stimulus identification and response selection, respectively.

In addition to the four *standard choice reaction tasks*, subjects performed on four selective stop tasks created by the same factorial combination of SD and SRC. The selective stop tasks were presented in conjunction with a go task in which subjects were required to discriminate between an angry vs. sad expression of the schematic face on the basis of the position of the eyebrows. On most trials, subjects responded to a change in the position of the eyebrows of the schematic face indicating an angry vs. sad face. Occasionally, pupils occurred in the schematic face requiring subjects to refrain from responding depending on the position of the pupils relative to the response activated in the go task. Based on the assumptions underlying the horse-race model of stopping, it was predicted that go RT should not be altered by the specific go-task by stop-task combination (i.e., go task + spatially compatible stop task with easy-to-discriminate stimuli, go task + spatially compatible stop task with difficult-to-discriminate stimuli, go task + spatially incompatible stop task with easy-to-discriminate stimuli, and go task + spatially incompatible stop task with difficult-to-discriminate stimuli). Most importantly, it was predicted that SD and SRC would produce additive effects on mean stopping RT.

2.1. Method

2.1.1. Participants

Twenty-four undergraduate students (18 females, mean age 21 years) participated to fulfill course requirements. All subjects reported to be healthy and had normal or corrected-to-normal vision.

2.1.2. Apparatus and signals

An IBM-compatible computer presented the signals and recorded the responses. A schematic face remained on screen during the tasks (see Fig. 1). The schematic face was drawn in black lines and presented against a light gray background at the center of a 15-in. computer monitor. Viewed at a distance of about 70 cm, the horizontal and vertical visual angles subtended by the face were approximately 5.5° and 6.5°.

In the standard choice reaction tasks, imperative signals were two black circles (diameter 4 mm) that appeared as pupils in the eyes of the schematic face. The pupils were presented on the horizontal mid-axis of the eyes, either 8 mm to the left or right with respect to the center of the eyes (i.e., easy-to-discriminate stimuli) or at a distance of 4 mm from the center, that is in the outer left or right canti of the eyes (i.e., difficult-to-discriminate stimuli).

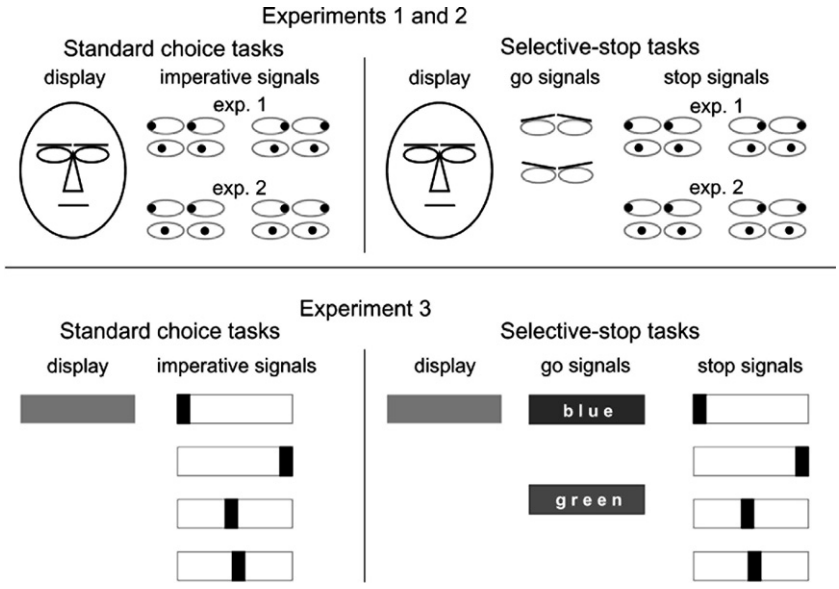

Fig. 1. Stimulus displays used in the standard choice reaction tasks and the selective stop tasks of Experiments 1, 2, and 3. The directional gaze (left vs. right) of the eyes (Experiments 1 and 2) and the location of the small square (Experiment 3) instructed the participants to activate a compatible or incompatible manual response in the standard choice tasks or to selectively inhibit their manual response in the selective stop tasks. Discriminability (high vs. less) and SRC condition (compatible vs. incompatible) were manipulated block wise. See text for further details.

In the four *selective stop tasks*, the imperative signals of the go task (go signals) were indicated by the position of two lines located 1 mm above the eyes of the schematic face that depicted the eyebrows. An imperative signal was indicated by tilting the far ends or the close ends of the eyebrows from a horizontal or neutral position, representing an angry vs. a sad expression. Imperative (eyebrow) signals were separated by intervals varying randomly and equiprobably from 1250 to 1750 ms in steps of 125 ms. The go signals were response terminated or their offset followed after 1000 ms if no key was pressed. The 'z' and the '/' keys on the computer keyboard recorded responses with the left and right index fingers with an accuracy of 1 ms. The stop signals were the same as the imperative signals used in the standard choice reaction tasks (i.e., left vs. right positioned pupils).

2.1.3. Tasks and design

Standard choice tasks. The within-subject variables of the factorial design were SD (easy vs. difficult-to-discriminate) and SRC (compatible vs. incompatible). In the easy-to-discriminate condition, subjects responded to eccentrically positioned pupils whereas in the difficult-to-discriminate condition they had to respond to pupils that were positioned close to the center of the eyes. In the spatially compatible condition, subjects were required to respond in the direction of the gaze of the schematic face whereas in the spatially incompatible condition they had to respond in the opposite direction.

Selective stop tasks. The go task was to discriminate between angry vs. sad expressions of schematic faces, created by tilting the eyebrows. On each trial, the eyebrows changed from a neutral position into an 'angry' or 'sad' position. Subjects were required to respond as quickly and accurately as possible to an angry face by pressing the 'z' key on the computer keyboard and to a sad face by pressing the '/' key (or vice versa). On 30% of the trials, the pupils in the schematic face appeared as a stop signal, shortly after the onset of the go signal. A tracking algorithm (Levitt, 1971) was used to obtain a percentage of successful response inhibition of approximately 50%. Upon successful stopping, stop-signal delay (i.e., the interval between the onset of the go signal and the stop signal) on the next stop trial was increased by 50 ms whereas upon failures to stop, stop-signal delay was reduced by 50 ms. The setting of stop-signal delays at the beginning of a block was taken from the final settings of the immediately preceding block of trials.

Four selective stop-signal tasks were administered, created by a factorial combination of stop-signal SD and stop-signal SRC. As in the standard choice reaction tasks described above, SD was manipulated by varying the distance of the pupils relative to the center of the eyes. Stop signals could appear, equiprobably, at a location that was either compatible (i.e., same location) or incompatible (i.e., opposite location) vis-à-vis the location of the correct response required by the go task. SRC was varied block wise, by instructing participants to inhibit their response, but only if the stop signal was presented at the side of the correct response (compatible stopping) or if the stop signal appeared on the opposite side of the correct response (incompatible stop-

ping). Consider, for example, a compatible stop task where an angry face is mapped onto a right-hand response and a sad face to a left-hand response. Subjects should then inhibit their go-task response but only if the eyes in the schematic face are looking at the correct response activated by the go task. Thus, a right-hand response to an angry face should be stopped only if the eyes are looking to the right. In the spatially incompatible stop-task, however, the response should be executed in spite of the presence of the stop signal (i.e., invalid stop trial). In the latter case, the response must be stopped when the gaze of the schematic face is directed towards the opposite hand (i.e., valid stop trial).

2.1.4. Procedure

Subjects performed their tasks in a quiet, dimly lit room in groups with a maximum of three in one session of about 3 h. Participants were instructed to respond as fast and accurately as possible to imperative signals. In the stop tasks, subjects were told not to delay their responses to increase their stopping chances should a stop signal occur. Furthermore, it was explained that stop-signal onset would vary across trials, and that some stop signals will occur early so that they will always be able to stop and some will occur late so that it is virtually impossible to refrain from responding.

Half of the subjects started the experimental session with the standard choice reaction tasks; the other half completed the stop tasks first. The standard choice reaction tasks were administered in eight blocks; two blocks of 100 trials each for each SD by SRC combination. Task order was counterbalanced across subjects and the initial block of every task was for practice only. The stimulus-response assignment of the go task in the stop-signal paradigm (i.e., eyebrow-to-hand mapping) was counterbalanced across subjects and did not change during the session. The go task was practiced in a separate training block of 100 trials without stop signals before the stop tasks were administered. The four stop tasks were presented for each SD and SRC condition containing four blocks of 120 trials each. Order was counterbalanced across subjects. Again, the first block was for practice only. Performance feedback was provided after each trial block. Trial blocks were separated by short intermissions and a longer rest separated the different tasks during which participants could move around freely. The first four trials of every task block were marked as warm-up trials and excluded from analysis.

2.1.5. Estimation procedure of SSRT

SSRTs were estimated using the hose-race model (Logan & Cowan, 1984). According to the independence assumption of the race model, the stop and response processes operate independently. The start of the stop process is under experimental control by the stop-signal delay, but the finish time of the stop process has to be inferred from the observed distribution of go-signal RTs (i.e., trials without a stop signal). The finish of the stop process bisects the go-RT distribution, with the left side of the distribution (representing fast responses) matching the distribution of RTs on stop trials that escape inhibition. If responses were not stopped on n% of the stop trials, the finish of the stop process is on average equal to the go RT marking the nth percentile of the go RT distribution. Finally, mean stop-signal delay is subtracted from this finishing time to obtain an estimate of SSRT (see Logan, 1994). Stop-signal tracking based on inhibition rates of approximately 50% provides stop latency estimates that are derived from the center of the go-RT distribution, and are relatively insensitive to violations of the assumptions of the race model (e.g., Band et al., 2003).

2.2. Results and discussion

Mean RTs were computed for correct trials after removal of outliers (i.e., RTs outside $M \pm 2.5SD$). Two subjects did not complete all of the standard choice tasks and were therefore excluded from subsequent analyses.

2.2.1. Standard choice tasks

Mean RTs of correct trials and choice error percentages were calculated per subject and analyzed in a 2×2-factorial design with SD (easy vs. difficult) and SRC (compatible vs. incompatible). The results obtained in the standard choice tasks are presented in Table 1. First, SD had a significant main effect on RT, $F(1,21) = 4.9$, $p < .05$, but not on choice errors, $F(1,21) = 1.0$, $p = .33$. RTs from trials with the easy-to-discriminate pupil positions ($M = 342$ ms) were slightly but significantly faster than RTs from the task blocks with hard-to-discriminate pupil positions ($M = 353$ ms). Second, SRC had a highly significant main effect on RT, $F(1,21) = 44.5$, $p < .001$, and on choice errors, $F(1,21) = 6.7$, $p = .02$, with faster and more correct responses on trials with compatible mapping ($M = 329$ ms) than with incompatible mapping ($M = 366$ ms). Finally, the effects of SD and SRC were additive, both for RT and errors, Fs < 1.

As predicted, the present findings showed an additive pattern of effects of SD and SRC on mean choice RT, suggesting that the present design successfully manipulated two independent stages of the choice reaction process – the stimulus identification stage and the response selection stage.

2.2.2. Selective stop tasks

2.2.2.1. Go trials. RT and error percentages on go-signal trials in the stop tasks are presented in Table 2. RTs to the primary-task stimulus did not vary significantly between stop tasks, $F < 1$. Neither did errors, $F < 1$.

Table 1
Mean reaction times (RT in ms), errors percentages, and standard deviations (in parentheses) for each combination of stimulus discriminability and S-R compatibility

Discriminability	Stimulus-response compatibility			
	Compatible		Incompatible	
	RT	Error (%)	RT	Error (%)
Experiment 1				
High	322 (42)	2.7 (2.3)	363 (53)	4.1 (3.4)
Less	336 (44)	3.0 (1.6)	370 (64)	4.8 (3.3)
Experiment 2				
High	316 (24)	3.9 (2.9)	356 (31)	5.2 (2.9)
Less	355 (25)	5.7 (3.6)	407 (43)	8.3 (4.9)
Experiment 3				
High	307 (32)	1.7 (1.9)	345 (32)	4.5 (3.2)
Less	392 (50)	11.5 (6.2)	455 (63)	12.9 (7.3)

Table 2
Mean RTs to go-signals and RTs following invalid stop signals (ms), mean errors percentages, and standard deviations (in parentheses) per Stop-SD and Stop-SRC condition in the selective stop tasks

Discriminability	Go signals				Invalid stop signals			
	Compatible		Incompatible		Compatible		Incompatible	
	RT	Error (%)	RT	Error (%)	RT	Error (%)	RT	Error (%)
Experiment 1								
High	404 (46)	2.8 (2.6)	401 (46)	3.6 (3.6)	525 (64)	8.2 (8.7)	527 (53)	4.1 (5.2)
Less	407 (53)	3.6 (4.3)	397 (41)	3.0 (2.1)	533 (58)	8.2 (7.7)	517 (74)	5.4 (5.1)
Experiment 2								
High	416 (45)	3.0 (2.0)	426 (35)	3.5 (2.1)	525 (56)	7.7 (5.4)	532 (47)	2.8 (4.8)
Less	416 (47)	3.7 (1.9)	420 (46)	3.5 (3.1)	526 (46)	7.3 (4.3)	534 (62)	3.3 (4.0)
Experiment 3								
High	486 (59)	2.6 (2.3)	512 (66)	2.3 (1.8)	620 (74)	3.9 (3.0)	622 (75)	2.8 (3.0)
Less	493 (54)	2.9 (2.2)	490 (50)	3.2 (2.6)	663 (86)	7.0 (9.6)	652 (88)	4.0 (4.1)

Invalid stop trials. Stop signals appearing opposite to the correct response hand in compatible stop tasks, and stop signals appearing on the same side as the correct response hand in incompatible stop tasks are invalid stop signals and go-task responses should not be inhibited. The ANOVA on RTs on invalid stop trials failed to discriminate between stop tasks, $F < 1$. As Table 2 shows, responses following invalid stop signals (526 ms) were considerably slower than responses to go trials (402 ms), $F(1,23) = 263.2$, $p < .001$.

Valid stop trials. Response probability was somewhat higher than the anticipated 50%, but the proportion of failed inhibits did not differ significantly between stop tasks, $F(3,21) = 2.5$, $p = .09$. Mean stop-signal delay in compatible stop tasks (160 ms) was longer than in incompatible stop tasks (133 ms), $F(3,23) = 6.9$, $p = .02$. Contrary to the prediction of the hose-race model, responses that escaped inhibition on stop trials (signal-respond RT 417 ms) were significantly slower than responses on go trials (402 ms), $F(1,23) = 8.3$, $p < .01$. The analysis of RTs for these signal-respond trials (i.e., go responses on stop trials that escaped inhibition) yielded main effects of SD (17 ms), $F(3,23) = 5.8$, $p = .03$, and SRC (32 ms), $F(1,23) = 18.7$, $p < .001$, but no interaction, $F(1,23) = 1.7$, $p = .20$.

Finally, and most importantly, the ANOVA performed on selective stop latencies revealed a significant effect of SRC, $F(1,23) = 8.0$, $p = .01$. SSRTs on incompatible trials were longer (276 ms) compared to SSRT on compatible trials (250 ms). SD failed to exert a significant effect on SSRT. SSRTs to easy-to-discriminate stop signals was 261 ms and SSRT to difficult-to-discriminate stop-signals was only slightly longer, 265 ms, $F < 1$. The interaction between SD and SRC failed to reach significance, $F(1,23) = 1.7$, $p = .20$.

In sum, although our manipulation of SD and SRC yielded the anticipated additive RT pattern for the standard choice tasks, SD failed to systematically affect SSRT in the selective stop tasks. Possibly, the manipulation of SD needs to be more demanding in order to exert an appreciable effect on SSRT. In order to explore this possibility, a median split was done ranking subjects according to the SD effect on the standard choice tasks. The resulting groups (large vs. small SD effect) were

then included as a between-subjects factor in an ANOVA, including SD and SRC as within-subject factors. This ANOVA yielded a significant higher-order interaction between the effects of Group, SD, and SRC. Separate group analyses indicated that the SD effect on SSRT was significant for the 'large SD-effect on-RT' group, $F(1,11) = 18.0$, $p < .001$; 237 vs. 256 ms for easy- vs. difficult-to-discriminate stop signals. But for this group the main effect of SRC on SSRT just failed to reach significance, $F(1,11) = 3.4$, $p = .09$. Finally, the SD and SRC effects on SSRT did not interact, $F < 1$. The finding of a significant SD effect on SSRT obtained for the group of subjects that appeared most sensitive to the SD manipulation prompted us to perform a second experiment in which the manipulation of SD was more demanding.

3. Experiment 2

This experiment was designed to provide a more potent manipulation of SD while keeping all other aspects of the experiment identical to the previous experiment. The size of the schematic face was reduced and thus the distance of the pupils relative to the center of the eyes. In the easy-to-discriminate condition, the distance was 4 mm and in the difficult-to-discriminate condition it was only 1 mm (recall that in the first experiment, the corresponding values were 8 vs. 4 mm). It was anticipated that increasing the demands on stimulus identification would result in a significant SD effect on both RT and SSRT.

3.1. Method

3.1.1. Participants

A different group of 15 undergraduate students (10 females, mean age = 21.2 years) participated to fulfill course requirements. All reported to be healthy and had normal or corrected-to-normal vision.

3.1.2. Apparatus and signals

The equipment was identical to the apparatus used in Experiment 1. The size of the schematic face employed in Experiment 1 was reduced by 50% (visual angles 2.75° × 3.25°). The pupils presented in the schematic face, serving as imperative signals in the standard choice tasks and as stop signals in the selective stop tasks, were positioned at a distance of 4 mm from the center of the eyes (easy-to-discriminate condition) or at a distance of 1 mm (difficult-to-discriminate condition).

3.1.3. Tasks, design, and procedure

Design, procedure, and instructions of the standard choice tasks and the selective stop tasks were similar to Experiment 1.

3.2. Results and discussion

Mean individual RTs were computed for correct trials only and outliers (i.e., RTs outside, $M \pm 2.5SD$) were removed.

3.2.1. Standard choice tasks

Trials without a response were less than .2%. Mean RTs of correct trials and choice error percentages were calculated per subject, for each factorial combination of SD and SRC. RTs and square roots of choice error percentages were analyzed in a 2×2-factorial design with SD (easy vs. difficult discrimination) and SRC (compatible vs. incompatible) as within-subject factors. The results obtained in the standard choice tasks are listed in Table 1. First, SD exerted a highly significant main effect on RT, $F(1,14) = 75.3$, $p < .001$, and choice errors, $F(1,14) = 8.6$, $p = .01$. Responses to difficult-to-discriminate stimuli (381 ms) were noticeably slower (45 ms) than responses to easy-to-discriminate stimuli (336 ms). Recall that in the previous experiment the SD effect size was only 11 ms. The main effect of SRC on RT and accuracy was also significant, $F(1,14) = 55.7$, $p < .001$, and $F(1,14) = 12.4$, $p < .01$, respectively. Compatible responses were faster (336 ms) and more accurate (4.8%) than incompatible responses (381 ms and 6.8%). Finally, SD and SRC exerted additive effects on both RT, $F(1,14) = 3.8$, $p < .05$, and accuracy, $F < 1$.

3.2.2. Selective stop tasks

Go trials. RTs and error percentages on go-signal trials in the stop tasks are presented in Table 2. RTs to go signals did not vary significantly between selective stop tasks, $F < 1$. Similarly, error percentages of the go task did not differ between selective stop tasks, $F(3,12) = 1.4$, $p = .29$.

Invalid stop trials. Recall that responses on trials with an invalid stop signal should not be inhibited. The ANOVA on RTs following invalid stop signals yielded no significant main effect of selective stop task, $F < 1$. As can be seen in Table 2, responses on invalid stop trials (529 ms) were substantially slower than responses on go trials (420 ms), $F(1,14) = 99.3$, $p < .001$.

Valid stop trials. Results obtained on valid stop trials are presented in Table 3. The proportion of failed inhibits was somewhat higher than the anticipated 50%. The probability of responding given a valid stop signal for the compatible stop tasks was 57% (easy SD) and 59% (difficult SD), and the corresponding values for the incompatible stop tasks were 56% and 59%. The proportion of failed inhibits did not differ significantly between stop tasks, $F(3,12) = 1.8$, $p = .20$. Likewise, mean stop-signal delay did not vary across stop tasks, $F(3,12) = 1.1$, $p = .37$.

Responses that escaped inhibition on stop trials (signal-respond RT 435 ms) did not differ significantly from

Table 3
Mean proportions of failed inhibits to valid stop-signals, stop-signal delay, failed-inhibit RT, stop-signal RT, and standard deviations for each selective stop task, resulting from the factorial combination of stop discriminability (Stop-SD) and Stop SRC

Stop-SD	Failed inhibition (%)				Stop-signal delay				Failed-inhibit RT				Stop-signal RT			
	Compatible		Incompatible		Compatible		Incompatible		Compatible		Incompatible		Compatible		Incompatible	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Experiment 1																
High	55	8	58	8	158	61	142	60	397	50	420	66	252	56	270	63
Less	55	6	58	9	162	65	124	46	406	58	446	56	248	41	282	68
Experiment 2																
High	57	9	56	10	138	62	145	49	415	51	442	50	283	54	288	55
Less	59	8	59	11	144	68	132	47	422	50	458	64	282	61	301	47
Experiment 3																
High	51	3	50	2	247	83	252	88	458	50	504	67	234	39	257	43
Less	51	3	52	4	231	89	231	80	505	70	513	69	261	54	260	53

responses on go trials (420 ms), $F(1,14) = 3.9$, $p < .05$. The ANOVA on signal-respond RTs yielded a significant effect of SRC, $F(1,14) = 11.7$, $p < .01$, but the effect of SD was not significant, $F < 1$. Finally, and unexpectedly, SSRTs did not differ between selective stop tasks, $F(3,12) = 1.9$, $p = .19$. The main effects of SD and SRC on SSRT failed to reach significance, $F(1,14) = 1.2$, $p = .30$, and $F(1,14) = 1.9$, $p = .19$, respectively. The interaction between these effects did not reach significance either, $F(1,14) = 1.1$, $p = .30$.

In sum, for standard choice RT, the experimental manipulations of SD and SRC replicated the additive pattern obtained in the first experiment. The more demanding SD manipulation resulted in a larger effect on RT but, in contrast to expectations, failed to exert an appreciable effect on stop RT. Possibly, the eyes in the schematic face provided a spatial reference so as to annihilate a potent effect on stimulus identification. Therefore, a final experiment was done using a different stimulus display.

4. Experiment 3

The display of the schematic face that was used in the previous experiment was replaced by a new display consisting of a horizontal bar presented at central location. The imperative stimuli were little squares that could be presented at one of four possible locations in the horizontal bar – either at the far left or far right of the bar (i.e., easy-to-discriminate stimuli) or close to central fixation (i.e., difficult-to-discriminate stimuli). These stimuli were used both in the standard choice tasks and in the selective stop tasks. In the selective stop tasks, a change in the color of the horizontal bar (gray-to-blue vs. gray-to-green) served as the imperative stimuli in the go task. Pilot work ensured that the new display resulted in a SD effect on mean choice RT that was about twice the size of the effect obtained in the previous experiment.

4.1. Method

4.1.1. Participants

A new group of subjects was recruited consisting of 21 undergraduate students (10 females, mean age = 23 years), participating to fulfill course requirements. All subjects reported to be healthy and had normal or corrected-to-normal vision.

4.2. Apparatus and signals

An IBM-compatible computer presented the signals and recorded the responses. In all tasks, a horizontal bar was presented at central fixation of a 15-in. computer screen (see Fig. 1). The bar (2 cm length × .5 cm

width) was presented in dark-gray against a light-gray background. Viewed at a distance of about 70 cm, the bar subtended a 1.6° horizontal and a 0.4° vertical visual angle. The imperative stimuli in the standard choice tasks and the selective stop tasks consisted of a small red square (2 mm length × .5 cm width) that could appear at one of four possible locations in the bar. The red squares were presented either 2 pixels to the left or right with respect to the vertical midline of the bar (i.e., difficult-to-discriminate stimuli) or at the far ends of the bar (i.e., easy-to-discriminate stimuli).

In the four selective stop tasks, the imperative signals of the go task were indicated by a change in the color of the bar – from gray to blue (RGB-code: 0 255 255) or from gray to green (RGB-code: 102 255 0). Imperative stimuli were separated by intervals varying randomly and equiprobably from 1250 to 1750 ms in steps of 125 ms. The imperative stimuli were response terminated or their offset followed after 1000 ms if no key had been pressed. The 'z' and the '/' keys on the computer keyboard recorded responses executed with the left- and right-index fingers.

4.2.1. Tasks, design, and procedure

Standard choice tasks. The within-subject factors of the factorial design were SD and SRC. In the standard choice tasks, subjects responded to the position (left or right) of the red square. SD was varied by positioning the square close (left vs. right) to the center of the bar (difficult-to-discriminate) or to the far ends (left vs. right) of the bar (easy-to-discriminate). The administration of the standard choice tasks was similar to Experiments 1 and 2.

Selective stop tasks. The go task in the stop-signal paradigm was to discriminate between blue vs. green colored bars by pressing the left key to the blue bar ('z' key on the keyboard) and the right key to the green bar ('/' key on the keyboard) (or vise versa) as quickly and accurately as possible. On 30% of the trials, a red square was presented as a selective stop stimulus shortly after the onset of the go stimulus. A tracking algorithm (Levitt, 1971) was used to obtain a percentage of successful response inhibition of approximately 50%. This and all other experimental procedures were identical to the ones employed in Experiments 1 and 2.

4.3. Results and discussion

4.3.1. Standard choice tasks

First, SD yielded a highly significant effect on mean choice RT, $F(1,20) = 114.8$, $p < .001$. Responses to difficult-to-discriminate stimuli were about 98 ms slower than responses to easy-to-discriminate stimuli. Error rates were higher when stimuli were difficult-to discriminate, $F(1,20) = 94.4$, $p < .001$. Second, the effect of SRC on mean choice RT was also highly significant, $F(1,20) = 134.9$, $p < .001$, with incompatible responses being 50 ms slower than compatible responses. Subjects committed more errors when required to execute an incompatible response (8.7%) relative to a compatible response (6.6%), $F(1,20) = 13.0$, $p < .01$. Third, there was a significant, over-additive, interaction between the effects of SD and SRC on mean choice RT, $F(1,20) = 6.8$, $p = .02$. That is, the effect of SD on choice RT was larger (111 ms) when an incompatible response had to be executed compared to the execution of a compatible response (85 ms).

4.4. Selective stop tasks

Go trials. Mean choice RTs to go signals in the selective stop tasks did not differentiate between stop compatibility, $F(1,20) = 3.0$, $p = .10$, and SD, $F(1,20) = 1.9$, $p = .18$. More errors were committed in the choice RT task if stop signals were harder to discriminate (3.0%) compared to easy-to-discriminate stop signals (2.5%), $F(1,20) = 6.0$, $p = .02$.

Invalid stop trials. The ANOVA performed on the RTs following invalid stop trials yielded a significant main effect of SD, $F(1,20) = 16.6$, $p < .001$, with faster responses to easy-to-discriminate stop stimuli (621 ms) relative to difficult-to-discriminate stop stimuli (658 ms). The main effect of SRC and the SD × SRC interaction were not significant, Fs < 1. On average, responses following invalid stop trials (640 ms) were slower than responses on go signals (496 ms) without a stop signal, $F(1,20) = 297.6$, $p < .001$.

Valid stop trials. As can be seen in Table 3, response rates on stop trials were close to 50%, indicating that the tracking algorithm worked well. Mean stop-signal delays were longer in the stop tasks with difficult-to-discriminate stop stimuli compared to easy-to-discriminate stimuli (249 vs. 231 ms), $F(1,20) = 5.0$, $p = .04$. Analysis of signal-respond RTs yielded significant main effects of SD (28 ms) and SRC (27 ms), $F(1,20) = 7.0$, $p = .02$, and $F(1,20) = 6.3$, $p = .02$, respectively. The interaction between SD and SRC was not significant, $F(1,20) = 1.9$, $p = .19$. Finally, the speed of responding on signal-respond trials (i.e., responses that escaped inhibition) was approximately similar to response speed on go trials, $F < 1$.

Most importantly, the ANOVA performed on SSRT yielded significant, albeit modest, effects of both SD (16 ms) and SRC (10 ms), $F(1,20) = 5.1$, $p = .04$ and $F(1,20) = 5.3$, $p = .03$, respectively. The cost of incompatible stopping was larger for easy-to-discriminate stimuli compared to difficult-to-discriminate stimuli. The SD by SRC interaction failed to reach significance, $F(1,20) = 2.7$, $p = .11$.

5. General discussion

The main purpose of this study was to examine the nature of selective stopping by using the AFM as a tool to identify separable components of the stopping process. The AFM has been used successfully to identify stages in the choice reaction process (Sternberg, 1969; for a review see Sanders, 1998). This research yielded a fair amount of evidence suggesting that the perceptual analysis of the imperative stimulus can be isolated from the selection of the appropriate response. The hypothesis guiding the current experiments simply assumed that the AFM allows for the decomposition of the stopping process similar to the identification of stages in the going process. Two manipulations were selected from the AFM literature, stimulus discrimination (SD) and stimulus-response compatibility (SRC). In previous reports, these manipulations have been shown to produce additive effects on mean choice RT (e.g., Pluister, 2004). Indeed, the results that emerged from Experiments 1 and 2 yielded significant main effects of SD and SRC on mean choice RT and these effects were additive. According to additive factors logic, this additive pattern can be taken to suggest the existence of two independent stages in the choice reaction process, a stimulus identification stage influenced by SD and a response selection stage influenced by SRC.

The same manipulations that were used to differentiate between components of the go process activated during the performance of the standard choice reaction tasks were taken to identify separable stages in stop processing during the performance of the selective stop tasks. Unfortunately, the SD manipulation, that had a sizeable effect on the duration of the go process in Experiments 1 and 2, turned out to be ineffective in changing the duration of selective stopping. In addition, although the SRC manipulation lengthened the duration of selective stopping in Experiment 1, it failed to influence selective stopping in Experiment 2. One possibility that should be considered when providing an account for the lack of SD effects (in both experiments) and SCR effects (in the second experiment) refers to potential violations of the race model that is used for estimating stopping times. In this regard, it should be noted first that the tracking algorithm worked well. Across experiments, the proportion of failed inhibits was approximately 50%, indicating that the estimates of stopping time were derived from the center of the go-RT distribution. Simulation studies indicated that estimates of stopping time derived from this part of the go RT distribution are fairly robust against violations of the race-model assumptions (Band, van der Molen, & Logan, 2003). Moreover, it should be noted that when subject performed the selective stop tasks, their go-signal RTs were not influenced by the various stop tasks. This is another indication that going and stopping were independent, as assumed by the horse-race model, that adds to the reliability of the current estimates of stopping times.

It could be argued, however, that the observed RTs of failed inhibits are not in line with the horse-race model. When subjects fail to detect the stop signal or when stop processes are relatively slow, the go process will win the race and the response activated by the go signal will be executed (i.e., a failed inhibit). The horse-race model predicts that failed inhibits are faster than mean RT on go trials. Indeed faster failed inhibits are typically observed when subjects are performing a global stop task with one (valid) stop signal (e.g., Band et al., 2003; Logan, 1994). The reversed pattern obtained in Experiments 1 and 2, that is, the RTs of failed inhibits were somewhat slower instead of faster than mean RTs on go trials, might suggest a violation of the model. In the current study, however, subjects performed a selective stop task requiring the translation of a bi-valued stop signal into a stop response, resulting into the inhibition of the response activated by the go signal. On some trials, subjects might fail to detect the stop signal and, on those trials, the speed of failed inhibits will be similar to mean go RT. On other trials, subjects detect the stop signal but processing of the stop signal is slow relative to the processing of the go signal. On those trials, failed inhibits are likely to be faster than mean go RT. Yet another possibility is that the translation of the stop signal results into an erroneous outcome and, consequently, the response activated by the go signal is executed like it is on invalid stop trials; i.e., trials on which the response activated by the go signal should be executed in spite of the presence of the stop signal. Most likely, the speed of failed inhibits following an erroneous outcome of stop-signal processing is close to mean RT on invalid stop trials (i.e., more than 100 ms slower than mean RT on go trials). Consequently, the distribution of failed-inhibit RTs contains short RTs due to stop-signal detection failures and/or fast stop-signal processing. On average, these RTs are shorter than mean RT on go trials, as predicted by the horse-race model. The apparent sluggishness of failed inhibits is due to stop-signal trials on which the processing of the stop signal resulted in an erroneous outcome. The plausibility of this reasoning can be tested by examining the distribution of failed-inhibit RTs. This distribution should be bimodal. Indeed, a test for bimodality yielded a significant outcome as suggested by the above reasoning.[1] It is then fair to conclude that the violation of the horse-race model was more apparent than real. Conse-

[1] The test that the distribution of failed-inhibit RTs (i.e., responses following a valid stop signal) is accurately described by bimodal distribution parameters yielded a probability of 0.66. Conversely, testing for unimodality yielded a relatively low probability of 0.02. These results confirmed the hypothesis that the failed-inhibit RTs are bimodality distributed. The mixture analyses were based on multimodality testing by kernel-density estimation (n simulations = 500) and were performed using the mode-testing program developed by Hartelman, van der Maas, and Molenaar (1998; for availability of the program, see van der Maas, 2004).

quently, there is no reason left to doubt that the current estimates of stopping times are reliable.

A third experiment was done, using a different stimulus display, to assess the effects of a more demanding manipulation of stimulus discrimination. The results that emerged from this experiment were in some respects similar to the findings obtained from the two previous experiments but in some regards they were different. The results were similar in that the RTs on go trials and the RTs of failed inhibits were approximately similar whereas the RTs following invalid stop trials were substantially slower. The results were different in that the effects of SD and SRC on mean go RT showed a significant over-additive interaction while the results of the two preceding experiments yielded an additive relation. Blind application of AFM logic would suggest that in the standard choice tasks of Experiment 3, SD and SRC affect a stage in common. But an over-additive interaction between the effects of two manipulations does not necessarily imply that these manipulations alter the rate of a single processing stage. Simulation studies performed by McClelland (1979) demonstrated that, even if it is assumed that processing occurs in a series of discrete stages, a manipulation affecting the output of a stage might produce an over-additive interaction with manipulations of the rate of any subsequent stage. Thus, the inferences of the additive factors logic are no longer valid when it is allowed that the output of a stage is a continuous variable rather than a discrete code. Accordingly, the over-additive interaction between the effects of SD and SRC on mean choice RT must be interpreted to suggest a SD effect on the output of the stimulus identification stage and a SRC effect on the rate of the response selection stage, not a combined effect on a single stage.

Most importantly, both the SD and SRC manipulations exerted a significant effect on the duration of the selective stopping process in Experiment 3, and the ANOVA performed on mean selective stopping RTs revealed an additive relation. The inspection of the exact pattern indicated that SD and SRC are involved in an under-additive, albeit non-significant, relation. That is, the effect of SD was more pronounced for compatible than incompatible responses. In the AFM literature, under-additive relations received two alternative interpretations, both assuming the existence of two separate processing stages. One interpretation, offered by Stanovich and Pachella (1977), assumes that when stimuli are difficult to discriminate, response selection can begin before the stimulus-identification stage is completely finished. According to this interpretation, there is temporal overlap between the stimulus-identification stage of stop-signal processing and the response-selection stage. An alternative interpretation, submitted by Sanders (1980), assumes that strong demands on stimulus processing might compromise the output of perceptual stages that is particularly harmful when the stimulus requires a compatible response. The current results cannot decide between these alternatives but it is important to stress that both interpretations assume the existence of two processing stages - one influenced by stimulus manipulations and the other by the compatibility of the required response. In other words, the current AFM application supported the existence of two independent stages in selective stopping – one altered by SD and the other by SRC.

In conclusion, the current study made an attempt at decomposing the selective stop process using the AFM that has been proven to be a powerful tool for examining the temporal structure of the choice reaction process. The results showed that manipulations of stimulus discriminability and stimulus-response compatibility yielded the anticipated effects on the choice reaction process. Making the stimulus more difficult to discriminate and requiring a spatially incompatible response resulted in a considerable lengthening of RT and, in two experiments, these effects contributed additively to the speed of responding. It proved more difficult to alter the speed of selective stopping using these manipulations. Thus, a relatively extreme stimulus discrimination manipulation yielded an effect of 98 ms on choice RT but of only 15 ms on selective stop RT. Most importantly, the pattern of results suggested that the temporal structure of the selective stop process is similar to the discrete stage structure of the choice reaction process. Hopefully, this finding will encourage future studies of selective stopping to assess the effects of other experimental manipulations on stages of the selective stop process. It is recommended that those studies employ fine-graded manipulations as the current experiments indicated that the exact pattern of results is critically dependent on the relative timing of going and stopping.

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