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The Multi-Source Interference Task: The Effect of Randomization

JOHN F. STINS, WESSEL M. A. VAN LEEUWEN, AND
ECO J. C. DE GEUS

Department of Biological Psychology, Free University of Amsterdam, Amsterdam, the Netherlands

Recently a novel interference task was developed, that was aimed at obtaining robust patterns of interference in individual subjects, both behaviorally and neurophysiologically (Bush, Shin, Holmes, Rosen & Vogt, 2003). This multi-source interference task (MSIT) combined elements of spatial and flanker interference, and huge interference effects were obtained in a blocked design. This task could thus in principle be used to assess frontal abnormalities, such as ADHD. In the present study, we further examined the nature of the MSIT. We examined the effect of randomization, and the relative contribution of each type of interference. Using a group of healthy subjects, we found a much smaller interference effect than Bush et al. (2003). In addition, we found that most of the interference could be ascribed to flanker interference, and much less to spatial interference. It seems to be the case that there is a trade-off between obtaining robust and reliable effects, and isolating a specific psychological process.

In daily life humans have access to a wealth of information. This information can originate from the outside environment, or can reside in memory (in the form of stored experiences). However, in order to act successfully we need to select task relevant information and ignore task irrelevant information. Selective attention enables one to process the task relevant inputs, thoughts, or actions while ignoring irrelevant or distracting ones. A common way to study selective attention experimentally is by analyzing how subjects respond to target stimuli in the presence or absence of distracting items of information. Typically, distractors are associated with a different response than the target, and unintentional processing of the distractor then interferes with the selection of the correct response. This response conflict has to be solved before the response can be given, which results in slightly worse performance (slower RTs and/or more errors), relative to the situation without response conflict.

The anterior cingulate cortex (ACC) is a brain structure that is implicated in the detection of conflict. This structure is typically activated while performing conflict tasks, such as Color Stroop (e.g., Bush et al., 1998; Ullsperger & Von Cramon, 2001), flanker (e.g., Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999) and spatial conflict (a.k.a. Simon) tasks (e.g., Peterson et al., 2002). Conflict tasks are of great interest with regard to research into the fundamentals of cognitive brain functioning. Furthermore, they are of interest to clinicians who search for tasks that can be used as a marker for ACC abnormalities, such as attention-deficit/hyperactivity disorder (e.g., Swanson, Castellanos, Murias, LaHoste, & Kennedy,

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Address correspondence to Eco J. C. de Geus, Department of Biological Psychology, Free University of Amsterdam, Van der Boechorststraat 1, 1080 BT Amsterdam, the Netherlands. E-mail: eco@psy.vu.nl

1998) and obsessive compulsive disorder (e.g., Van Veen & Carter, 2002). However, the standard interference tasks often do not produce strong and/or consistent enough interference (both behaviorally and neurophysiologically) to be used for diagnostic purposes. In fact, interference is usually only evident after group averaging of the data. This state of affairs led Bush, Shin, Holmes, Rosen, and Vogt (2003) to develop a novel task that was aimed at robustly activating the ACC *within individual subjects*. This task was labeled the Multi-Source Interference Task (MSIT) and, according to the authors, combined both Stroop, flanker, and Simon interference. Using functional magnetic resonance imaging (fMRI), their results indeed revealed significant ACC activation in each of their eight (healthy) subjects. In addition, they found a staggering 312-ms average interference effect, which is orders of magnitude higher than in the more standard interference tasks (typically well below 100 ms).

These promising first results make the MSIT a potential useful addition to the existing neurobehavioral test repertoire. However, before the MSIT can be used for clinical purposes it is important to establish the exact meaning of the performance parameters, most notably the interference effect. We have two questions concerning the interference effect: First, is the size of the effect found by Bush et al. (2003) due to the blocking of the trials? And second, what is the relative contribution of spatial interference and flanker interference to the total interference effect? Our first question is motivated by the fact that Bush et al. (2003) administered the stimuli using a blocked design, i.e., blocks containing only control stimuli were alternated with blocks containing only interference stimuli. However, this grouping of stimuli may induce unknown processing strategies in subjects. In fact, it is more common to administer different stimulus types (congruent vs. incongruent, or control vs. interference) in a random fashion. Randomization of trial types is assumed to prevent subjects from adopting a strategy whereby they, say, adjust their overall level of conflict monitoring on some blocks of trials. Blocking of trials thus creates a potential confound, which may hamper the interpretation of the interference effect. In the present experiment control and interference trials were therefore presented in a random order.

Our second question involves the relative contribution of both types of interference. The MSIT interference stimuli used by Bush et al. (2003) contain elements of flanker interference (distracting items flanking the target) and Simon interference (incongruity between the position of the target and the position of the response). The total interference score can be thought of as the combined influence of both types of interference. However, in order to assess the clinical relevance of the MSIT it would be good to know the relative contribution of both types of interference to the total interference score. For example, with respect to ADHD, we know that patients in general suffer more from flanker interference than controls (e.g., Crone, Jennings, & van der Molen, 2003), whereas both groups suffer to an equal degree from the spatial incongruity between stimulus and response (e.g., Yong-Liang et al., 2000). We decided to explore the relative contribution of the two kinds of interference using a new type of stimulus, which contains only distracting flanker items, but no spatial incongruity between target location within the stimulus array and response location. This manipulation allows us to estimate which type of interference weighs most heavily in the total MSIT interference score.

Method

Participants

Thirty-three adult students and staff from both the Vrije Universiteit and the Universiteit van Amsterdam participated (mean age 24.9 years, SD 5.3 years, range 18–43 years;

26 women, 7 men; 27 right handed, 6 left handed). All participants reported normal or corrected to normal vision and no neurological symptoms.

Material

Subjects were, during the entire experiment, sitting about 45 cm in front of a computer screen on which all stimuli were presented. Stimuli consisted of a horizontal array of three numbers (1 and/or 2 and/or 3) and/or letters (x) printed in white (font: Tahoma) that appeared in the center of the screen against a black background. The numbers appeared either in a large font (height 2 cm) or in a smaller font (height 1.5 cm). The height of the x-es was 1 cm. The width of the array of symbols was between 3.5 and 4 cm, dependent on the stimuli. In front of subjects was a purpose-made button pad with one home button and three response buttons, arranged so that the distance between the home button and each of the three response buttons was the same (14 cm). The distance between each of the response buttons was 8 cm. Subjects were told that the response buttons represented, from left to right, the numbers one, two, and three. Subjects were instructed to keep the home-button pressed with the fingers of their preferred hand, and to respond to the stimulus by (a) releasing this button as soon as they had decided which response button to press, and then (b) pressing the appropriate response button, and then (c) returning to the home location. Speed and accuracy were stressed.

The computer registered the reaction time (i.e., the interval between stimulus onset and release of the home button), the total time TT (i.e., the interval between stimulus onset and the moment at which the response button was pressed), and which of the three response buttons was pressed. The time it takes to cover the distance between the home button and the response button (the movement time) is simply the difference between total time and reaction time. Our measure of primary interest was the RT which represents the first observable finger movement in response to the stimulus. However, the Bush et al. (2003) study differs in a subtle way from ours, in that they employed key *presses*, instead of key *releases* (as in our design). Therefore, in order to facilitate comparisons between the studies we also examined the TTs.

MSIT task

Three types of stimuli were used, viz., control, uni-source interference, and multi-source interference stimuli. With all stimuli, subjects had to identify the number that was different from the other two items, and press the corresponding response button. In addition, with both kinds of interference stimuli, the target element was always printed either in a larger or a smaller font than the two distractor elements. In the control stimuli the target element was always printed larger. This size manipulation was also adopted by Bush et al. (2003), but did not affect the RTs.

For each of the three stimuli, we used all possible combinations of target identity, position, flanker identity, and font size. This gives rise to three control stimuli, twelve uni-source interference stimuli (the factorial combination of two font sizes, two identities of the flanking numbers, and three target numbers), and twenty-four different multi-source interference stimuli (the factorial combination of two font sizes, two identities of the flanking numbers, three target numbers, and two different positions of the target number). The complete set of stimuli is shown in Table 1.

In the experiment subjects received 150 stimuli; all three types in a random order, and in an equal number. The experiment was preceded by 5 practice trials.

Table 1
The complete set of stimuli used in the experiment. Each stimulus consists of a set of three numerals and/or x'es. Note that the odd one is always printed in a smaller or a larger font than the two distractor items. S = Stimulus. R = Required response

Control	Uni-Source interference			Multi-Source interference		
S - R	S - R	S - R	S - R	S - R	S - R	S - R
1xx - 1	122 - 1	323 - 2	212 - 1	331 - 1	112 - 2	322 - 3
x2x - 2	122 - 1	323 - 2	212 - 1	331 - 1	112 - 2	322 - 3
xx3 - 3	133 - 1	113 - 3	313 - 1	211 - 2	332 - 2	131 - 3
	133 - 1	113 - 3	313 - 1	211 - 2	332 - 2	131 - 3
	121 - 2	223 - 3	221 - 1	233 - 2	311 - 3	232 - 3
	121 - 2	223 - 3	221 - 1	233 - 2	311 - 3	232 - 3

Data Reduction and Analysis

For each of the three stimulus types we calculated the mean RT and the mean TT, averaged over subjects. The following trials were counted as errors. Trials on which RTs were either faster than 150 ms or slower than 1500 ms, trials on which movement times were either faster than 80 ms or slower than 1000 ms[1], and trials that resulted in an incorrect response. We used analyses on variance (ANOVA) to examine the effect of stimulus type on performance.

Results

One subject was excluded from the analyses because she did not follow the instructions. The percentage of trials that were discarded from the remaining subjects due to the criteria described above was 2.0%.

Accuracy

Subjects responded 100% correctly on control stimuli. On average 99.8% of the responses on uni-source interference stimuli were correct, and 96.6% of responses on multi-source interference stimuli were correct. A repeated measures one-way ANOVA on these percentages revealed that these differences were significant ($F\ (2,62) = 16.81$, $p < 0.001$). Post hoc t-tests (with Bonferroni correction) showed that the level of accuracy on multi-source interference stimuli was less than on the other two kinds ($t(31) = 4.24$ (compared to control), $t\ (31) = 4.92$ (compared to uni-source interference) $p < 0.001$). Accuracy on uni-source interference stimuli was not statistically different from accuracy on multi-source interference stimuli.

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[1] This latter criterion was adopted because it was observed that on rare occassions subjects first raised their hand from the home button in response to the stimulus, and only thereafter — with their hand still in mid air — made a decision which response button to press. This manner of response execution was not as instructed and yielded extraordinary high movement times. Hence the cut-off.

Reaction Time

All subjects exhibited a positive uni-source interference effect (RT uni-source interference minus RT control), ranging from 12.12 ms to 139.01 ms, with the exception of one subject, who had a negative 3-ms effect. Further, all had a positive multi-source interference effect (RT multi-source interference minus RT control), ranging from 12.27 ms to 206.46 ms. Finally, 28 subjects exhibited a larger average reaction time on multi-source interference stimuli than on uni-source interference stimuli. This difference ranged from 1.1 ms to 99.54 ms. The mean RT for control, uni-source interference, and multi-source interference stimuli was 495, 550, and 576 ms, respectively. An ANOVA on the RTs revealed that these differences were significant (F (2, 62) = 87.23, $p < 0.001$). Post hoc paired t-tests (with Bonferroni corrections) showed that all pair-wise differences were significant: control stimuli versus uni-source interference stimuli: t (31) = 9.45, $p < 0.001$; uni-source interference stimuli versus multi-source interference stimuli: t (31) = 5.77, $p < 0.001$; control stimuli versus multi source interference stimuli: t (31) – 10.18, $p < 0.001$.

Total Time

The same ANOVA performed on the TT yielded a similar pattern of results. The mean TT for control, uni-source interference, and multi-source interference stimuli was 726, 818, and 901 ms, respectively. An ANOVA revealed that these differences were significant (F (2,62) = 238.20, $p < 0.001$). Post hoc paired t-tests (with Bonferroni corrections) showed that all pair-wise differences were significant: control stimuli versus uni-source interference stimuli: t (31) = 11.31, $p < 0.001$; uni-source interference stimuli versus multi-source interference stimuli: t (31) = 13.19, $p < 0.001$; control stimuli versus multi-source interference stimuli: t (31) = 18.72, $p < 0.001$.

Discussion

This study was designed to further investigate the nature of a newly developed interference task, which yielded highly promising results in the Bush et al. (2003) study. Our study had two aims, related to (a) the effect of blocking on the interference effect, and (b) the relative contribution of the two types of interference to the total interference effect. Starting with the latter, we introduced a third type of stimulus in order to separate these two sources of interference. This uni-source interference stimulus differed only in one respect from the multi-source interference stimulus, namely the absence of spatial conflict between target and response, since the position of the target identity always matched the response position. We hypothesized that the interference effect would be somewhat smaller on uni-source interference stimuli as compared to multi-source interference stimuli. Our hypothesis was confirmed, as our RT analyses revealed a uni-source interference effect of 55 ms and a multi-source interference effect of 81 ms, and even larger effects when the total time was considered. Since we argued that in uni-source interference stimuli the only source of interference was the presence of flankers, it appears that the flanker interference contributes for 55 ms to the overall interference effect. The remaining 26 ms are then due to spatial incompatibility interference. This analysis of course assumes that the two sources of interference behave in an additive fashion, which isn't necessarily so. For example, Hommel (1997) found an underadditive interaction between Simon (in)congruity and flanker (in)congruity. On the other hand, the sizes of the observed interference effects are clearly consistent with the existing literature (for an overview, see Bush et al., 2003), showing that flanker interference is on average larger than interference due to spatial stimulus-response incongruity.

Our second aim was to investigate the effect of randomization on the interference effect. This manipulation had a huge effect on performance; it dropped from 312 ms (the blocked version of Bush et al., 2003) to 81 ms in our randomized version. It is well-known that in interference experiments the effect of blocking is such that the interference effect is somewhat larger than in a randomized design. For example, the literature suggests that the size of the Simon effect is about 30 ms, whereas when the spatial (in)compatibility between stimulus and response is blocked, the effect is larger; about 50 ms (for an overview of spatial correspondence effects, see Hommel and Prinz, 1997). In a similar vein, it was found in a computerized single-trial version of the Stroop test that the interference effect was larger when the Stroop items (congruent, incongruent, and neutral) were presented in blocks than when they varied on a trial-by-trial basis (Salo, Henik, & Robertson, 2001). It thus seems to be the case that our smaller interference effect is due to our randomization manipulation.

However, the huge discrepancy between the *size* of our interference effect and Bush et al.'s (2003) is puzzling, for which we present the following tentative explanation. Simply put, we believe that the blocks of control stimuli and interference stimuli used by Bush et al. (2003) differ in more than one respect. Although their assumption, which is based on subtractive logic, is that the only difference between the blocks concerns the presence or absence of interference, we can think of at least two other important differences that may differentially affect RT. First, with the control stimuli there was strictly speaking no need to process the identity of the item. Given that the position of the odd one out was always congruent with its position, subjects needed in principle only to attend to the position within the array that visually "popped out" from the rest, and press the spatially compatible response button. Thus in a block of control stimuli there was no need for subjects to engage in semantic processing, whereas this type of processing was essential in the block of interference stimuli. Second, and relatedly, it might be the case that during blocks of control trials subjects resorted to a strategy involving simple and automatic stimulus-to-response translation, which requires limited attentional resources. As a result, their level of arousal was arguably lower than during blocks of interference trials, which are clearly attention demanding.

If this line of reasoning is correct, it is not surprising that Bush et al. (2003) found such strong effects (both behaviorally and neurophysiologically), because the two experimental conditions are different in so many respects, for example computationally and energetically. On the other hand, this state of affairs makes it difficult to determine exactly which processes are involved in the two task versions which, in turn, may limit the validity of the MSIT for diagnostic purposes. Future versions of the MSIT should try to keep the level of semantic processing constant across conditions, by either requiring subjects to always engage in semantic processing, or by devising interference stimuli (uni or multi source) that do not require semantic processing at all, for example, with elementary visual symbols.

In general, our experimental efforts are guided by two demands; the demand to obtain robust and reliable effects, and the demand to isolate and capture a well-defined psychological construct. These two demands are often in conflict, because a gain in one tends to lead to a loss in the other. The Bush et al. (2003) study was aimed at obtaining robust and reliable effects; our own research efforts were guided by the wish to isolate a specific psychological process. The ideal neuropsychological test should satisfy both criteria.

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