A Brain Programmer for Increasing Human Information Processing Capacity

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Abstract—*Brain programming has been used to increase human working memory capacity, also called processing resources, a major determinant of information processing efficiency. Previously only methods for decreasing working memory capacity existed. Brain programming increased the amount of information that could be handled by a person simultaneously or within a certain period of time, and resulted in improved accuracy or speed in processing of images (pattern recognition), words and math problems. Analyses of variance of error rate and response time revealed a significant effect of the brain programmer, as compared with music used as a control. The pattern of the effects of the brain programmer on error rate and response time was consistent with an increase in the capacity of working memory. This research shows that the capacity of working memory, acting as information processing resources, plays an important part in ordinary cognitive performances, and can be improved by brain programming.*

Index Terms—*pattern recognition, images, letters, words, math, accuracy, response time, improvement, human cognitive performances, brain programming, working memory capacity, information processing resources*

1. *Introduction*

Processing resources have been variously referred to as attentional capacity, working-memory capacity, speed of processing, and so on. Salthouse (1985, 1988) concluded that the bulk of the references to the concept of processing resources could be encompassed within three categories organized around the metaphors of space, energy, and time.

The space metaphor is based on the idea that there is a finite working-memory capacity that determines the amount of short-term storage or computation that is simultaneously possible. The metaphor of resources as energy is reflected in references characterizing processing resources as some type of attentional capacity that functions as a general-purpose “fuel” for information processing. The conceptualization of time as a processing resource is based on the idea that the quicker or faster cognitive operations are executed the more likely it is that other operations can be initiated, and that processing dependent upon multiple operations will be accurately completed.

Methods have been suggested in the past for *decreasing* processing resources. They include a double-stimulation, psychological refractory period (PRP) method proposed by Pashler (Pashler & Johnston, 1989; Welford, 1952). In this method, two stimuli were presented in quick succession, so that the second one falls in the refractory period of the first, then processing resources are reduced and neural noise levels are increased. Dual task (Logan & Burkell, 1986) is another method. When a subject is doing two tasks simultaneously, the processing resources for each task are reduced compared with single task performance. Increased age is often associated with poorer performance on certain commonly used tests of cognitive functioning. This has been attributed to decreased processing resources, or working memory capacity.

2. *Approach and Procedures*

The goal of increasing information processing capacity and improving human cognitive performance has been pursued by the author with a new approach, brain programming, a groundbreaking invention. Brain programming is based on two properties of human cognition: universality and associability. Universality means all types of cognitive activities involve common structures and functions in the central nervous system. There is an innate equivalency among different types of perceived information, be it visual, auditory, lingual, mathematical, etc. Consequently one type of stimulus can stand for, or represent, another type, just as in algebra a letter A can stand for different numbers, and represent them in a formula of math calculation, and can be supplanted by these real numbers when calculation actually begins. Associability means a link can be established between two stimuli by repeated pairing. If we repeat a sequence of stimuli in the order A→B→C→D for a number of times, next time when A occurs B, C and D will be likely to follow in the same order, and we say A is a signal for B, C, D. If we repeat them in a different order, for example A→D→C→B, for a number of times, next time when A occurs, D, C, B will be likely to follow, and A is a signal for D, C, B.

Using these principles, a brain programmer has been designed to increase the processing resources. Its major component is a brain program. The brain program increases the capacity of working memory by timely modifying certain aspects of the working memory that are common to all types of cognitive activity, that is, by making proper, periodical changes in chunking properties and patterns of activities. If the working memory handles a piece of information as a single chunk, it can handle it reliably and efficiently; but if the working memory can handle a multitude of pieces of information as so many chunks, it will have a large capacity. These two contradictory demands on the working memory are optimally met with periodical changes in the chunking properties of the working memory. First the working memory is made to hold all its information as one chunk, and then multiple chunks are repeatedly combined together so that the working memory is made to hold a large number of chunks at the next moment. Then next the working memory should hold all the information it has received as one chunk again, and the whole process repeats itself. So the chunking property, or compartmentalization, of the working memory should ideally change periodically, or cyclically. But the presence of multiple chunks, or compartments, does not necessarily mean every one of them is actively holding a piece of information, or is turned on. As the periodical changes of chunking properties goes from cycle to cycle, new information gradually fills up, or turns on, larger and larger proportion of the multitude of available compartments, giving rise to a gradually changing "pattern of activities" in the working memory. When most of the compartments are filled up, they should be emptied out, or turned off again, to make room for new information. So the proportion of active compartments of successive patterns of activities in the working memory should increase gradually and then drop abruptly in a periodical manner. And this period is longer than the period in the cyclic changes in chunking property, or compartmentalization, since it takes a number of cycles in the periodical changes in compartmentalization to fill up a multitude of compartments and complete one cycle in the periodical changes in the pattern of activities.

To properly guide the two periodical changes, computer-generated sound signals (or stimuli) are arranged in a brain program, recorded on an audio-recording device, played back and heard by a person, and thus stored in his/her long-term memory (LTM). Later, the memorized stimuli of the brain program are recalled subliminally from LTM. The process of memorizing and recalling the brain program is automatic without the person knowing it or making any effort. Some stimuli in the brain program are surrogates for pieces of information to be processed and, when recalled during cognitive performance, will be supplanted by these pieces of information to be processed. Other stimuli are put in such places in the brain program, for example just before a surrogate stimulus, that, when recalled, they will be associated with these pieces of information to be processed through conditioning, and thus become signals, or "carriers", for these information being processed. The stimuli in the brain program are arranged in such a way as to enable pieces of information being processed, when they have supplanted their surrogates and become inserted in the brain program, to interact with each other, thus achieving the periodical changes in chunking property and in patterns of activities in the working memory. These sound signals are short music tones generated by a computer, are identified by their pitch (frequencies), and are the main part of a brain program that is called a computerized auditory brain program (CABP), which also includes verbal signals.

The memory of CABP has to be recalled subconsciously at a faster speed than the speed at which it was presented to a person. That is, the recalled CABP has to be instantiated, as all the steps in a cycle of CABP have to be recalled into a person's mind in an instant, if they are to have any effects on the ongoing information processing. Instantiation of recalled CABP is facilitated by a trick in the way CABP is presented and stored in the long-term memory. During CABP presentation, two identical sequences of sound signals are presented, the first at a lower speed and the second at a higher speed. The difference in speed is small enough to make the two sequences sound like the same so that the long-term memory will hold a single copy of the sequence, but big enough to make the time taken by the two sequences indefinite in the long-term memory. That is, the two sequences are fused into one sequence in the long-term memory (LTM) that keeps the characteristics, such as pitch of a sound signal and sound-duration-to-interval ratio, that are the same in the original two sequences and thus strengthen each other in the LTM, but loses characteristics, such as speed and time taken, that are different for the two original sequences and thus cancel each other out in the LTM. Then the time taken by the recalled brain program will have to be determined anew. In the two sequences, the information about the time taken by a cycle is loaded onto a very short time period that is embodied in intervals between repeating signals. As a result the brain program is recalled at a speed much higher than the speed of either of the two original sequences. Thus instantiation is achieved, and a cycle of different steps takes only an instant to complete. As a result, a large amount of processing resources is always available to receive and process new information. So CABP actually contains two sequences of sound signals, but they result in one brain program.

Besides the brain program CABP, the other major component of the brain programmer is a reinforcement system. The reinforcement system uses single brief vibratory signals to refresh the memory of CABP over time. Actually it is the lengths of intervals between discrete vibratory pulses that are being used as signals which are associated with CABP through conditioning and therefore subsequently arouse the memory of CABP. The intervals between discrete vibratory pulses are stronger signals than the pulses themselves. These intervals are easy to manipulate. A time interval T can be halved to another interval T/2, or give rise to T/3 or T/4. These slightly changed versions, when presented, will resonate with the memory of the original T, and therefore can be used in place of T, which has been associated with CABP, thus avoiding undesirable repetition of a single time interval as a signal, which would weaken the association between the signal and the event it evokes. In the reinforcement system these modified versions of a time interval T are incorporated into a sequence of single brief vibratory pulses whose intervals range from under 20 seconds to over a minute. When used in conjunction with CABP, the reinforcement system first gives a single vibratory pulse at both the beginning and end of a time interval T in the CABP that contains a number of repetitions of a verbal signal, "now start", which has been associated with the main part of CABP during its playback. After CABP playback has ended and the person is performing cognitive tasks with increased processing resources, the reinforcement system continues to give this person a sequence of vibratory pulses whose intervals are related to interval T in different ways (T/3, T/4, etc) as mentioned above. The recalled memory of the interval T elicits the memory of those repetitions of the verbal signal, each of which in turn contributes a strengthening effect to the memory of the brain program CABP. Thus the memory of CABP is constantly refreshed and its effectiveness maintained over time.

Since the brain programmer has its effects on the most basic properties of cognitive functioning, it can be used to improve all kinds of cognitive performances.

3. Preliminary Studies:

Predictions based on metaphors of processing resources as space, time, and energy:

1. Letter match with short exposure time.

The visual elements of the image of a letter are called pixels. The minimal number of independent pixels necessary for recognition of a letter depends on the complexity of the visual features of the letter. The "white" or "black" color of each pixel, or its "on" or "off" state, must cause a corresponding change in the functioning of an independent unit in the working memory. In other words, each pixel must be represented by a functional unit in the working memory. When the exposure time is as short as 50 ms per letter, the number of pixels representing the visual features of each letter must be caught by a working memory at once, or they will be lost. There is no time for sequential processing by the working memory. As a result, even before treatment the response time is expected to be short after a number of trials. But some visual features of the letters are lost because of the limited capacity of the working memory, resulting in higher error rate. After treatment with the brain programmer, the error rate should be reduced with no appreciable change in response time.

2. <u>Word recognition with exposure-until-response.</u>

A load of information contained in a trial with a word or non-word can be put sequentially through a working memory with a limited capacity, so the response time should be longer before treatment. Following treatment with the brain programmer, the capacity of the working memory will be increased, and will allow for parallel processing of some information. An increase in speed is therefore expected in an experimental group treated with the brain programmer, but only after a number of trials in which the processing of certain information can be reorganized from a sequential to a parallel mode of operation. Because there is no time limitation on a response, the information will be processed to the same extent before and after the increase in processing speed. Hence no significant change in error rate is expected.

3. <u>Multiplication verification in younger and older adults.</u>

In multiplication verification, the limited capacity of a working memory will be a bottleneck in information processing, especially for older adults and difficult trials (e.g. zero problems), forcing the information to be processed sequentially in a longer response time before treatment. By increasing the capacity of the working memory and switching to a parallel mode of processing for some information, the brain programmer is expected to reduce the response time after a number of trials, without change in error rate, and its effects should be stronger for older adults and difficult trials (e.g. zero problems).

Test Procedures The only thing a subject was instructed to do during testing was to perceive a stimulus on a computer screen and push a response key as accurately and quickly as possible. During playback of music or CABP a subject did nothing except listening. Subjects were briefed on the experimental objectives only after testing.

3.1 Experiment 1 Letter Match with Short (50 MS) Exposure Time (Fig. 1)

Forty undergraduate students (average age 22.9 years) were divided randomly into an experimental group and a control group. Each subject received three test sessions of trials for a total of 360 experimental trials. Each test session contained 120 trials, including 12 sets of repetitions of each of the five target letters F, G, J, K, and L (i.e., 60 "same" trials) and three instances each of the 20 possible permutations from picking two different letters out of this set of five letters (i.e. 60 "different" trials). The two letters appeared at adjacent places at the center of a computer screen for 50 ms each, separated by 50 ms, the one on the left preceding the one on the right. All subjects received a 10-minute music break between Test 1 and Test 2. In a 31-minute period between Test 2 and Test 3, subjects in the control group listened to music, whereas subjects in the experimental group received treatment with computerized auditory brain program (CABP), followed by a sequence of single brief pulses of vibration at both wrists.

There were no statistically significant differences in response times or error rates between the experimental and control groups in the two pretreatment test sessions.

The effect of the brain programmer on error rate (ER) in the experimental group was shown as a significant difference between the two groups in the change in ER after treatment, but not as a difference in absolute ER values of Test 3 between the two treatment type groups (Fig. 1). There was no effect on response time.

An analysis of variance of net changes of error rates from Test 2 to Test 3, DF_{ER}, revealed a significant main effect for treatment type ($F(1,76)=9.46$, $p<.01$, $MS_e=9.9$). The mean net change in percent error rate was –1.33% in the experimental group, and was 0.83% in the control group. There was no significant main effect for problem type ($F(1,76)=2.74$, $p>.1$), or interaction between treatment type and problem type ($F(1,76)=0.90$, $p>.1$).

3.2 Experiment 2 Word Recognition with Exposure-Until-Response (Fig. 2)

A total of 24 undergraduate students (average age 22.75 years) participated, 12 in an experimental group and 12 in a control group). Six test sessions were given to each subject, with a 10-minute music break between Tests 2 and 3 and 31 minutes of music or CABP between Tests 4 and 5 in the control or experimental group, respectively. Each test session consisted of four blocks of trials in the order: 1) lower case, non-spaced; 2) mixed case, non-spaced; 3) lower case spaced; 4) mixed case spaced. Each block contained 50 trials, 25 words and 25 non-words, in a random order. A word or non-word appeared at the center of a computer screen until a response key was pressed.

There were no statistically significant differences in response times or error rates between the experimental and control groups in the four pretreatment test sessions.

Note in Fig. 2 that in the experimental group, the reduction in mean RT following CABP was apparent only after a delay, so it showed up not in the first block of trials after treatment (block 17 in Test 5, compared with its counterpart, block 13 in Test 4 used as a pretreatment baseline), but in all seven subsequent blocks

For Test 5, the first test session after treatment, a 2 X 2 X 2 X 2 (treatment type by case by space-no-space by word-non-word) analysis of variance revealed a main effect for treatment type ($F(1,176)=6.81$, $p<.01$, $MS_e=6,141$) on the mean response time, which was 564 ms for the experimental group and 593 for the control group; and a significant main effect of treatment type ($F(1,176)=4.97$, $p<.05$, $MS_e=2,127$) on the mean net change $D1_{RT}$ from baseline RT of Test 4, which was –17 ms in the experimental group and –2 ms in the control group (Fig.2).. Treatment type did not have any effect on error rate or net change in error rate.

For Test 6, the second test session after treatment, a 2 X 2 X 2 X 2 (treatment type by case by space-no-space by word-non-word) analysis of variance revealed a main effect for treatment type ($F(1,176)=12.26$, $p<.001$, $MS_e=4{,}720$) on the mean response time, which was 550 ms for the experimental group and 584 ms for the control group; and a significant main effect of treatment type ($F(1,176)=9.09$, $p<.01$, $MS_e=2{,}124$) on the mean net change $D2_{RT}$ in response time, which was –31 ms in the experimental group and –11 ms in the control group (Fig.2). Treatment type did not have any effect on error rate or net change in error rate.

3. 3 Experiment 3 Multiplication Verification in Younger and Older Adults (Fig. 3)

A total of 80 subjects participated in the experiment, 20 in each of four groups: younger control, younger experimental, older control, and older experimental. The 40 younger adults (mean age=20.6 years, range 17-43 years) were undergraduate students and the 40 older adults (mean age=70.9 years, range 62-83 years) were local residents.

The 100 basic multiplication facts and one set of their false counterparts made up a total of 200 different problems. These 200 problems were divided into two parts of 100 problems each, which were used in Tests 1 and 2, respectively. Test 3 used the same problems as those used in Test 1. The 100 basic multiplication facts and another set of their false counterparts constituted a second set of 200 problems, and were used in Tests 4 and 5, each of which contained 100 trials. A problem appeared at the center of a computer screen for 500 ms.

There were no statistically significant differences in response times or error rates between the experimental and control groups in the three pretreatment test sessions. In all tests sessions, older adults had longer response times, especially for zero problems (Fig. 3). This finding is corroborated by observations on patients with brain damage, who showed selective impairment of multiplication on zero problems (Sokol et al. 1991; McCloskey, Aliminosa, & Sokol, 1991).

For Test 4, the first test after treatment, analyses of variance of RT and ER and their net changes did not show any significant main effects or interactions for treatment type.

For Test 5, the second test after treatment, RT was significantly different between the two treatment groups, a 2 X 2 X 2 X 2 (treatment type by age by zero-nonzero by true-false) analysis of variance revealed a main effect of treatment type ($F(1,303)=7.12$, $p<.01$, $MS_e=80{,}695$). The mean response time was 1007 ms for experimental group and 1092 ms for the control group.

For the mean net change in RT from Test 3 to Test 5, $D2_{RT}$, a 2 X 2 X 2 X 2 (treatment type by age by zero-nonzero by true-false) analysis of variance revealed a main effect of treatment type ($F(1,302)=10.69$, $p<.01$, $MS_e=28{,}948$). On average response time decreased by 120 ms between Test 3 and Test 5 (from 1127 to 1007 ms) for the experimental group, and by 58 ms for control group (from 1150 to 1092 ms). There was a treatment type by age interaction ($F(1,302)=6.51$, $p<.05$), the difference in mean net change $D2_{RT}$ between experimental and control groups was larger among older adults than among younger adults. In older adults, the mean $D2_{RT}$ was -154 ms (from 1379 to 1225 ms) for experimental group and -45 ms (from 1339 to 1294 ms) for control group; in younger adults, the mean $D2_{RT}$ was -87 ms (from 879 to 792 ms) for experimental group and -72 ms (from 962 to 890 ms) in control group. Therefore, overall the effects of treatment with the brain programmer were mostly seen in older adults. There was a treatment type by age by zero-nonzero interaction ($F(1,302)=6.9$, $p<.01$), that was a result of the fact that in older adults the difference in RT reduction between experimental and control groups was larger for zero problems than for non-zero problems. For zero problems the mean $D2_{RT}$ was -197 ms (from 1466 to 1269 ms) in experimental group and -17 ms (from 1407 to 1390 ms) in control group; for non-zero problems the mean $D2_{RT}$ was -112 ms (from 1294 to 1182 ms) in experimental group and -72 ms (from 1271 to 1199 ms) in control group (Fig. 3). In younger adults, the opposite was true, the difference in $D2_{RT}$ between experimental and control groups was larger for nonzero problems than for zero problems. For nonzero problems the mean $D2_{RT}$ was -93 ms (from 893 to 800 ms) in experimental group and -52 ms (from 944 to 892 ms) in control group; for zero problems the mean $D2_{RT}$ was -79 ms (from 864 to 785 ms) in the experimental group and -92 ms (from 981 to 889 ms) in the control group (Fig. 3).

4. Recent Developments of the Technology

The two playbacks of the Computerized Auditory Brain Program (CABP) at different speeds have been re-recorded on the two stereo sound channels (tracks) of a new version of CABP. When played back, the two playbacks of CABP at different speeds are heard through a set of stereo earphones by the two ears respectively at the same time.

At the same time that the subject is listening to the brain program (CABP), visual and vibratory pulses compiled in a reinforcing program are given in a time-dependent manner to different areas of the visual field (central and peripheral) or different areas of body surface (hands, wrists, arms, thighs, feet) to stimulate different areas of the brain (Berne and Levy, 1983, Penfield and Rasmussen, 1950). At each pair of symmetric locations of the visual field or body surface, pulses are given to the two sides in a pattern, for example Both-Left-Right—Both-Right-Left-----Both-Left-Right. And the patterns are followed by all kinds of reinforcing pulses. This reinforcing program is stored in long-term memory, along with the brain program (CABP). Later on, when information processing begins, a sequence of discrete reinforcing vibratory pulses is given to the person at the two sides of the waist. These reinforcing vibratory pulses refresh and reinforce the memory of the brain program (CABP) through the reinforcing program that has also been stored in the long-term memory and recalled, and their reinforcing effects are mediated through different areas of the cerebral cortex representing the different locations in the visual field or body surface in a time-dependent manner. In this way the memory of CABP is reinforced more efficiently, and fatigue and headache that could result from intense mental activities are prevented.

5. Conclusion

The brain programmer can increase human information processing resources, or working memory capacity, and can be used to improve all kinds of human cognitive performances. Its use is very simple and convenient, with no danger or side effects. It uses ordinary stimulus with currently available technology, involving no high-cost equipment.

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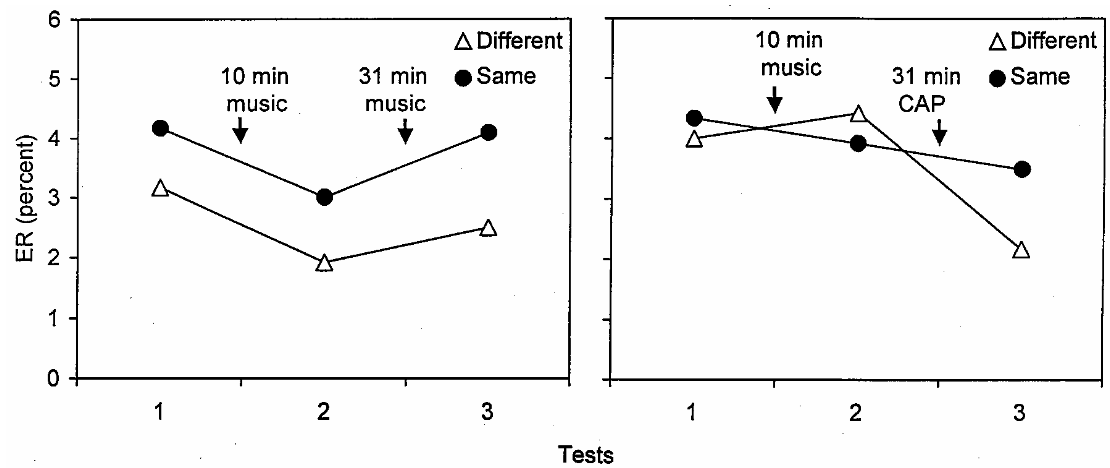
Figure Legends

Figure 1 Mean percent error rates (ER) for control (left panel) and experimental (right panel) groups in letter match experiment. Group mean is calculated over 20 subjects in each group. Mean net change in ER from pretreatment baseline Test 2 to Test 3 is significantly different between control and experimental groups.

Figure 2 Mean response times (RT) for control (left panel) and experimental (right panel) groups in word recognition experiment. The following 50 very high frequency words (VHF, range=240–1,016 occurrences in the Kucera & Francis, 1967, norms) and 50 non-words, obtained by changing the last letter of each word, were used:

	Words								
take	know	done	group	past	year	must	body	better	next
those	went	word	face	matter	though	hands	human	began	name
come	house	money	sense	power	part	found	rather	second	taken
never	turned	feet	days	today	water	course	church	need	become
before	number	system	four	room	toward	words	best	case	seemed
	Non-words								
taky	knop	donu	groun	pasc	yeag	musp	bodt	betteo	nexd
thost	wenk	worw	fack	matteg	thouga	handt	humax	begap	namp
coms	houst	monez	senso	poweg	parb	founy	rathek	secons	taket
neveg	turnek	feeg	dayn	todao	watev	courso	churce	neek	becomy
beforn	numbet	systeg	fous	roob	towarp	wordn	besc	casb	seemek

Figure 3 Mean response times (RT) for zero (zr) and nonzero (nz) problems in each test session in younger (Yg) and older (Od) subjects. The data points are mean RTs calculated over true and false problems for the 20 subjects in each group. Note the longer RT, especially for zero problems, in older subjects. Compared to control group treated with music (left panel), the reduction in mean RT from Test 3 to Test 5 after the brain program CABP in the experimental group (right panel) was larger for older subjects than for younger subjects. For older subjects, the reduction in mean RT was larger for zero problems, whereas for younger subjects the reduction was mainly in nonzero problems.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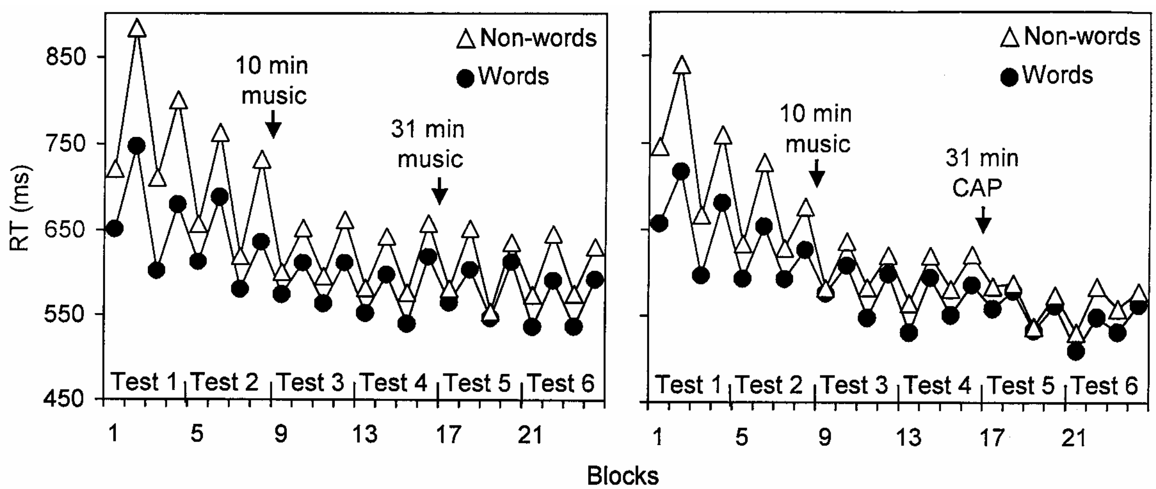
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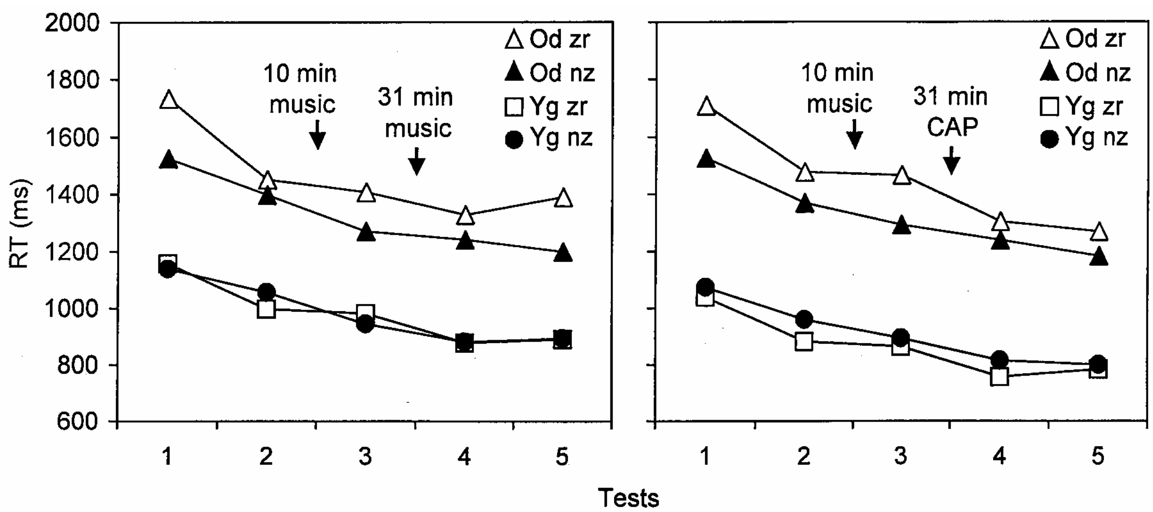
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