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CONCURRENCE COSTS IN NON–SPEEDED SECONDARY TASKS

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SUMMARY

Two experiments are reported on dual task concurrence costs in which participants executed a simple reaction time response to an auditory stimulus, followed by an explicitly non–speeded second response. In addition, the second response merely had to be produced; no stimulus triggered the response. In both experiments, the secondary tasks consisted of simply reaching over and picking up a lightweight object, or a heavy object. In Experiment 1, the objects were either a Nerf ball (0.12kg) or a standard 2.27kg brick. In Experiment 2, the nerf ball was replaced with a styrofoam brick identical in shape and size to the standard brick. The primary interest was in the effect on simple reaction time as a function of the nature of the secondary tasks. Results of Experiment 1 revealed that, compared to the single task control condition, both secondary tasks produced significantly longer reaction times, and more so for the lightweight nerf ball. In Experiment 2, however, these reaction time delays were eliminated. Taken together, our results suggest that when the shape and size of the secondary object is controlled, the weight of the object does not withhold any attentional resources from the primary task.

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INTRODUCTION

This article reports two experiments designed to investigate the attention demands of a primary simple reaction time (RT) task, S_1 — R_1, when it is performed alone, compared with its performance when combined with a non–speeded secondary task (S_1 — R_1, R_2). The work is based on an earlier study by Noble et al (1981), who discovered a "concurrence cost" when participants had to divide attention between a speeded primary task and a non–speeded secondary task. According to Sanders (1997), "Concurrence costs refer to the potential difference in maximal performance on a task when it is either performed single or together with another task but with all resources allocated to itself."

Noble et al, (1981) conducted six experiments with an S_1 — R_1, S_2 — R_2 paradigm. S_1 — R_1 was always a 2–choice reaction time task requiring a button push to either a high or low tone. S_2 was either a set of vertical or horizontal lines appearing on a screen. Participants had to simply say aloud "vertical" or "horizontal" as the response. The important feature of all experiments was that while participants were instructed to respond as quickly as possible to S_1, they were instructed not to respond quickly to S_2. In fact, they were told that R_2 should not occur until at least one second after the appearance of S_2, and that even longer was possible. Noble et al, (1981) were interested in the effects

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ABBREVIATIONS:
- ISI interstimulus interval
- RT reaction time

KEY WORDS:
attention deficits
divided attention

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on RT_1 in the double stimulation conditions compared to a single stimulation control. Thus, this paradigm is different than the typical psychological refractory period effect (Creamer, 1963; Davis, 1959; Kantowitz, 1974a, b; Karlin and Kestenbaum, 1968; Telford, 1931), where the interest centers on the second reaction, RT_2, in the double stimulation condition, compared to a single stimulation control. The difficulty of Noble et al, (1981) S_2 — R_2 task was manipulated by varying the interstimulus interval (ISIs ranged from 200 to 2600msec), S_2 duration (10 – 500msec), and the presence or absence of a backward masking signal.

The basic finding across all experiments was that, compared to the single stimulus control condition, RT_1 showed a constant delay of about 20 – 30msec. The only exception occurred at a very long ISI of 2600msec, where mean RT_1 for double stimulus trials was not significantly longer than for the single stimulus control trials. In a seventh experiment, S_1 — R_1 was always a simple RT task (only the high tone was used), and S_2 — R_2 required a non–speeded simple identification response (only the vertical lines were used). Therefore, participants had to merely report its occurrence. Results again revealed a significant elevation in RT_1. Noble et al, (1981) interpreted their findings in terms of some kind of basic concurrence cost resulting from simply the mere presence of a second task that, even though requiring no capacity, nevertheless consumed some resources from the first task (see also Navon and Gopher, 1979).

While the results of Noble et al, (1981) appear to defy older views of limited capacity or resource explanations of divided attention deficits (Welford, 1967, 1980) mainly because of the non–speeded nature of their R_2, it is still possible that the attention demands resulting from the very brief durations of S_2 (only 10 – 500msec) caused participants to devote more capacity to that task than would be necessary without S_1 — R_1. The present experiments addressed the following question: What happens to simple RT in a dual task situation if we remove the second stimulus, and the secondary tasks are non–speeded, in other words, an [S_1 — R_1, R_2 only] design? Without the need to monitor a second stimulus, and with no time pressure to produce the secondary tasks, there should theoretically be no drain on capacity or resources for the primary task, and its RT should be as fast as a control condition (primary task only). A second question addressed in Experiment 1 deals with the nature of the secondary tasks. We used two secondary tasks: in one, participants had to reach over and pick up a lightweight Nerf ball (approximately 0.12kg). In the second, they picked up a standard brick weighing 2.27kg. Does the difference in the weight of the secondary task objects drain any attention capacity from the primary task? There is some recent research showing that an object's orientation and size can affect human reaching and prehension movements (Desmurget et al, 1998; Paulignan et al, 1997; Pryde et al, 1998; Roby et al, 2000; Zaal and Bootsma, 1993). If there is a divided attention deficit (i.e., a concurrence cost), simple RT should be longer in the secondary task conditions compared to the control condition, and more so for the heavy object. However, if performance on the tasks does not suffer from capacity limitations, no RT delay is expected.

EXPERIMENT 1

METHOD

Participants

Fourteen female and ten male undergraduate students (M(age)=21.6years, SD=0.88) from Auburn University participated in exchange for course credit. The study was approved by the appropriate Institutional Review Board, and each participant gave informed consent before beginning the experiment.

Apparatus and Tasks

An Automatic Performance Analyzer (APA, Dekan Timing Devices, model 741A) was used to measure the reaction time in milliseconds. For the primary task (control condition), participants sat at a standard table (0.74m height) and placed their right hand on a 6.35cm x 7.62cm block of wood attached to a standard telegraph key located 15.24cm from the edge of the table. The left hand rested in their lap. Participants were given a verbal "get set" signal from the experimenter, who then pressed the trial-initiate button on the APA. Following a variable foreperiod of 1-3 seconds, an auditory stimulus sounded, to which the participants reacted by lifting their right hand from the telegraph key as quickly as possible. The experimenter recorded the reaction time, reset the APA, and then issued the next "get set" signal.

There were two secondary tasks, which differed in the weight of an object to be lifted. For the first (lightweight object), participants performed the primary task, as described above, executing it as fast as possible. After completing that task, participants reached 38.1cm across midline with their right hand and picked up a lightweight (0.12kg) orange–colored nerf ball (30cm circumference), lifting it approximately 15cm above the table, and then slowly put it back down. The nerf ball rested on three small circular pieces of wood (1.3cm diameter x 0.8cm high) to prevent it from rolling on the table. This secondary task was non-speeded. Participants were explicitly instructed to wait at least 2 seconds after completing the primary task before dealing with the secondary task. For the second secondary task (heavy object), participants followed the same instructions as described above, except that the object lifted was a standard red brick (6.35cm(H) x 8.89cm(W) x 20.32cm(L)) weighing 2.27kg. The brick was placed flat on the three pieces of wood and was oriented vertically in relation to the seated participant.

Procedures

Participants attended one 30 minute session consisting of 5 practice trials and 20 test trials of each of the three tasks described above. The order of performing the tasks was quasi-randomly assigned to participants, with all possible order combinations being used. At the beginning of each condition, participants were instructed how to carry out the task. It was stressed that the primary task should be performed as quickly as possible, but that the secondary tasks should be non–speeded. Participants were given a two minute break after each condition. The experiment required approximately 30 minutes per participant.

Results and Discussion

Each participant's mean reaction time was calculated for the 20 test trials in each condition. These means were subjected to a repeated measures analysis of variance (ANOVA) conducted at an alpha level of 0.05. The ANOVA revealed a significant effect for condition, $F(2,46)=13.44$, $p<0.001$, $n^2=0.37$. A Tukey HSD post–hoc test conducted at the 0.05 level revealed significant pairwise differences among all three means. The control condition produced the fastest RT (M=169ms, SD=18.8), followed by the heavy brick (M=179ms, SD=24.3), and then the lightweight Nerf ball (M=189ms, SD=33.1).

There are two findings of interest here. First, a concurrence cost was present, as simple RT was longer in both secondary task conditions compared to the control condition. This finding, in and of itself, is difficult to reconcile with older views of limited capacity or resource explanations of divided attention deficits (Welford, 1967, 1980), nor can it be explained by more recent views (Detweiler and Schneider, 1991; Navon, 1989a, b; Neumann, 1987; see Sanders, 1997 for a review). There is simply no theoretical reason to expect a divided attention deficit given the extreme simplicity of the primary task, combined with the non–speeded nature of the secondary tasks.

Second, even if we accept that the secondary tasks drained some capacity from the primary task, the nature of this drain was opposite to what we hypothesized in the introduction to Experiment 1. That is, RT for the lightweight nerf ball was longer than RT for the heavy brick. Our hypothesis was based on the assumption that object weight was the relevant dimension in the secondary tasks, and that the heavy object might require more capacity or resources than the light object. However, weight was not the only characteristic that distinguished our two secondary task objects. They also differed in shape, size, and orientation, and it is possible that participants perceived a greater demand for precision needed to pick up the Nerf ball than the brick (Paulignan et al, 1997; Zaal and Bootsma, 1993). Zaal and Bootsma (1993) had participants reach for and pick up wooden disks that differed in both size (3, 5 and 7cm diameter) and shape (round vs. oblong). No effect on movement time was found for the range of object diameters, but a significant difference in movement time was found for object shape. Zaal and Bootsma (1993) concluded that the surface area available for contact was an important determinant of movement duration. Our Nerf ball had a smaller amount of surface area available for contact than did the brick, so it is possible that this characteristic may have affected the prehension planning processes. Therefore, we decided to conduct a second experiment in which the Nerf ball was replaced with a lightweight white styrofoam brick, identical in shape and size to the standard brick. The purpose of Experiment 2 was to determine whether the weight of the secondary task object still withholds attentional resources from the primary task when the shape and size of the secondary object is controlled for.

EXPERIMENT 2

METHOD

Participants

Eighteen female and ten male undergraduate students (M(age)=21.6years, SD=3.1) from Auburn University participated in exchange for course credit. The study was approved by the appropriate Institutional Review Board, and each participant gave informed consent before beginning the experiment.

Apparatus and Tasks

The apparatus and tasks were identical to those of Experiment 1, with the following exception. For secondary task 1 (lightweight object), the Nerf ball was replaced with a lightweight (0.12kg) white styrofoam brick (6.35cm(H) x 8.89cm(W) x 20.32cm(L)). These dimensions were the same as those of the standard brick, and the texture of the styrofoam brick was similar in coarseness to the standard brick. Therefore, weight was the major difference between the two secondary task objects.

Procedures

All procedures were the same as in Experiment 1.

Results and Discussion

Each participant's mean reaction time was calculated for the 20 test trials in each condition. These means were subjected to a repeated measures ANOVA conducted at an alpha level of 0.05. The ANOVA revealed a non-significant effect for condition, $F(2,54)=1.40$, $p>0.05$, $n^2=0.049$. Although RT for the control condition (M=174ms, SD=25.0) was faster than the heavy brick (M=177ms, SD=24.2) and the styrofoam brick (M=180ms, SD=23.2), these differences failed to reach significance. Thus, a concurrence cost was not found in this experiment, suggesting that no additional resources were withheld from the primary task.

GENERAL DISCUSSION

Noble et al, (1981) found an extremely robust delay in RT_1 in a double stimulation paradigm in which the second response was always non–speeded. The delay was independent of several properties of S_2 — R_2 such as its processing demands, duration, ISIs up to 1000msec, or the presence or absence of a backward masking signal. The only condition in which the delay disappeared contained a very long ISI (2600 msec) combined with instructions to participants that S_1 and S_2 should be considered as separate tasks.

Noble et al, (1981) described the delay as representing a basic concurrence cost when two tasks are carried out in fairly close succession, even though the second task requires no capacity. Our Experiment 1 provided data that unexpectedly supported the concurrence cost findings of Noble et al, in that RT for both secondary tasks was elevated over that of the single task control condition. What was even more surprising was that the delay for our lightweight Nerf ball was greater than for the heavy brick. These data failed to support our expectation that the attentional resource demands might be greater for lifting a heavy object than for a light object. However, research on human prehension suggests that factors other than weight can affect reaching and prehension (Desmurget et al, 1998; Paulignan et al, 1997; Pryde et al, 1998; Roby–Brami et al, 2000; Zaal and Bootsma, 1993). In Experiment 2, when the secondary objects' shape and size were controlled, no RT delays were found.

At this point, we have provided more of a description, rather than an explanation, of a phenomenon that defies traditional accounts of divided attention deficits. Just as Noble et al, (1981) had difficulty accounting for their findings, so do we. It must remain for future research to shed further light on this interesting phenomenon.

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