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Use of the Secondary Task Technique for Tracking User Attention

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INTRODUCTION

The notion that the human information processing system has a limit in resource capacity has been used for over 100 years as the basis for the investigation of a variety of constructs and processes, such as mental workload, mental effort, attention, elaboration, information overload, and such. The *dual task* or *secondary task technique* presumes that the consumption of processing capacity by one task will leave less capacity available for the processing of a second concurrent task. When both tasks attempt to consume more capacity than is available, the performance of one or both tasks must suffer, and this will presumably result in the observation of degraded task performance.

Consider, for example, the amount of mental effort devoted to solving a difficult arithmetic problem. If a person is asked to tap a pattern with a finger while solving the problem, we might be able to discover the more difficult parts of the problem solving process by observing changes in the performance of the secondary task of finger tapping. While a participant is reading a chapter of text in a book or on a Web browser, we might be able to use this same technique to find the more interesting, involving, or confusing passages of the text. Many implementations of the secondary task technique have been used for more than a century, such as the maintenance of hand pressure (Lechner, Bradbury, & Bradley, 1998; Welch, 1898), the maintenance of finger tapping patterns (Friedman, Polson, & Dafoe, 1988; Jastrow, 1892; Kantowitz & Knight, 1976), the performance of mental arithmetic (Bahrick, Noble, & Fitts, 1954; Wogalter & Usher, 1999), and the speed of reaction time to an occasional flash of light, a beep, or a clicking sound (e.g., Bourdin, Teasdale, & Nourgier, 1998; Owen, Lord, & Cooper, 1995; Posener & Bois, 1971).

In using the secondary task technique, the participant is asked to perform a secondary task, such as tapping a finger in a pattern, while performing the primary task of interest. By tracking changes in secondary task performance (e.g., observing erratic finger tapping), we can track changes in processing resources being consumed by the primary task. This technique has been used in a wide variety of disciplines and situations. It has been used in advertising to study the effects of more or less suspenseful parts of a TV program on commercials (Owen et al., 1995) and in studying the effects of time-compressed audio commercials (Moore, Hausknecht, & Thamodaran, 1986). It has been used in sports to detect attention demands during horseshoe pitching (Prezuhy & Etnier, 2001) and rock climbing (Bourdin et al., 1998), while others have used it to study attention associated with posture control in patients who are older or suffering from brain disease (e.g., Maylor & Wing, 1996; Muller, Redfern, Furman, & Jennings, 2004). Murray, Holland, and Beason (1998) used a dual task study to detect the attention demands of speaking in people who suffer from aphasia after a stroke. Others have used the secondary task technique to study the attention demands of automobile driving (e.g., Baron & Kalsher, 1998), including the effects of distractions such as mobile telephones (Patten, Kircher, Ostlund, & Nilsson, 2004) and the potential of a fragrance to improve alertness (Schieber, Werner, & Larsen, 2000). Koukounas and McCabe (2001) and Koukounas and Over (1999) have used it to study the allocation of attention resources during sexual arousal.

The notion of decreased secondary task performance due to a limited-capacity processing system is not simply a laboratory curiosity. Consider, for example, the crash of a Jetstream 3101 airplane as it was approaching for landing, killing all on board. The airplane had deviated slightly from its course, and shortly after, the flight crew declared an emergency to the approach controller, attributing engine failure as the cause. The U.S. National Transportation Safety Board (NTSB, 2000), however, concluded that the airplane simply ran out of fuel and that the crew had not considered this possibility. The airplane's performance capabilities and simulator tests suggested that the flight crew still should have been able to land the airplane with the first engine out, with the second engine erratic, or with both engines out. The NTSB report surmised that the failure of the first engine could have caused the pilots to "fixate on instruments such as the altitude indicator and airspeed indicator and to allow the course heading to wander" (NTSB).

In the same way, we can observe erratic or degraded performance on tasks that are performed concurrently with other ordinary, everyday tasks, such as watching TV, reading from a book or computer screen, or driving a car. If we can observe erratic or degraded performance on a secondary task, then we can presume that the primary task of watching TV, reading, or browsing a Web site is consuming quite a lot of the person's mental processing capacity. There are three conclusions that we can draw from such observations.

1. We need to consider this limited capacity of the human processing system and the potential for dysfunctional performance when designing human-machine systems such as aircraft, automobiles, ordinary and everyday office computer applications, Web sites, and so forth.
2. We can use this observation of degraded performance on concurrent tasks as a way to identify human overload or failure points in a human-machine system.
3. We can use this observation of degraded performance as a measure of a variety of human mental processes, such as attention, mental effort, information overload, and such.

The first issue is the motivation behind this article. The remainder of this article, however, will focus on the latter two issues. First will be a brief theoretical discussion on how interference or dysfunctional mental processing performance occurs from a black-box perspective of the system. This will be followed by a discussion of how this interference can be observed with the so-called dual task or secondary task technique, used in the measure of mental overload, mental attention, mental effort, and such.

BACKGROUND

The concept of information overload is based on the assumption that the human information processing system has a limit in its capacity to process information. Most of us could effortlessly add two 2-digit numbers, but would experience extreme difficulty in attempting to add three 10-digit numbers without some additional scratch-pad memory in the form of a pencil and paper. The operationalization of evidence for information overload relies on the probability of errors in task performance.

Studies in the 1950s and 1960s attempted to locate a bottleneck in the processing system as if it was a single-channel serial transmission line (cf Welford, 1967). Broadbent (1954, 1957) proposed that there was a many-to-one selection switch in the channel, with throughput limited by how fast this switch could operate in selecting parallel input signals. Moray (1967), however, proposed that the system behaved instead like a flexible central processor of limited capacity.

The idea of a limited-capacity central processor was furthered by Kahneman (1973), Kerr (1973), and others. The idea was that the processing system is very flexible in the kinds of tasks that it can process concurrently at any given instant, but that it is very limited in its overall size. Kahneman viewed the earlier models of processing as explanations of structural limitations in processing. We cannot, for example, focus our eyes on two objects simultaneously. The limited-capacity processor model was proposed by Kahneman and contemporaries as an explanation of how some mental processing tasks can be performed concurrently.

There is currently no single correct view of the mechanisms that cause the human processing system to be limited in its ability to process information. Importantly, we know that the human processing system is not just a single-resource processor, but that there are multiple resources that can be limited (cf Friedman et al., 1988; Rollins & Hendricks, 1980; Triesman & Davies, 1973). From a practical per-