University of Utah
UNDERGRADUATE RESEARCH JOURNAL

QUANTIFYING THE COST OF INTERRUPTIONS ON VISUAL SEARCH

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Introduction

Recent estimates have placed medical errors as the third leading cause of death in America (Makary & Daniel, 2016). Each year, medical errors are responsible for approximately 100,000 deaths and an additional 1 million injuries in the United States alone (Kohn, Corrigan, & Donaldson, 2000). The field of diagnostic radiology plays a central role in disease management mainly through various medical imagining procedures (e.g., searching for cancer nodules in CT scans). During the difficult process of analyzing and interpreting medical images through visual search, radiologists experience interruptions on a frequent basis. These interruptions have been identified as a prevalent and potentially harmful occurrence in radiology reading rooms. Recent studies have linked interruptions to increased discrepancies between residents and attending physicians (Balint et al., 2014). Interruptions have also been tied to an increased error rate in other medical tasks, such as dispensing of medication (Westbrook et al., 2010).

We define visual search as a type of perceptual task that requires attention and typically involves an active scan of the visual environment for a particular object or feature (the target) amongst other objects or features (the distractors) (Treisman, Gelade, 1980). The purpose of this study was to quantify the cost of interruptions on visual search in terms of error rate and search time. Effects of interruptions on foraging in human visual search were also computed.

Methods

To simulate visual search performed by radiologists, participants were asked to conduct a task in which they were instructed to search for multiple targets amongst an array of distractors. In this experiment, targets were Landolt C's positioned in a specific orientation and the distractors were additional Landolt C's turned in different fashions (A Landolt C is a standardized symbol used for testing vision. It consists of a ring that has a gap, thus looking similar to the letter C. The gap can be oriented in various positions). Throughout the experiment, the participants primary visual search task was interrupted by a secondary task involving either a set of math problems, or a mental rotation problem. In order to determine an interruption's effect on visual search we computed trial duration, accuracy of target detection and the observers average click-rate. In addition, two versions of the experiment were conducted; version one contained an average of 7 targets, and version two contained an average of 41 targets.

Results

Search time experiment 1

Our data revealed that participants spent a significantly longer time searching interrupted cases (Math Interruption: M=100.04 s, SD=53.57 s; Mental Rotation: M=94.22 s, SD= 43.48 s) than control cases (M=89.87 s, SD=52.31 s).

Math interruption + control trials mean comparison: $t(19)=3.66$, $p=.001$, Cohen's $d=0.20$

Mental rotation + control trials mean comparison: $t(19)=2.23$, $p=.03$, Cohen's $d=0.09$

The average time cost for math interruptions was 10.17 s (median: 11.43 s, range:-20 to 30s), an 11% increase in search time when compared to control cases. Average time cost for mental rotation interruption was 4.34 s (median: 5.86 s, range: -41 to 18s), a 4% increase in search time when compared to control cases.

Interruption type comparisons show math interruptions (M=100.04 s, SD=53.57 s) as leading to a slightly longer search time than mental rotation interruptions (M=94.22 s, SD= 43.48 s), $t(19)=1.97$, $p=.06$, Cohen's $d=0.09$.

Search time experiment 2

In experiment two, results indicated that participants spent significantly more time searching math interruption cases (M=122.32s, SD=38.66 s) than control cases (M=115.75 s, SD=32.02 s), $t(20)=2.29$, $p=.03$, Cohen's $d=0.19$. However, search time for trials involving a mental rotation task (M=118.17 s, SD=35.42 s) did not vary significantly from control cases (M=115.75 s, SD=32.02 s), $t(20)=1.02$, $p=0.3$, Cohen's $d=0.07$.

The average time cost for math interruption was 6.56 s (median: 4.58 s, range: -25 to 37 s), a 6% increase in search time when compared to control cases. Average time cost for mental rotation interruption was 2.42 s (median: 5.25 s, range: -39 to 29 s) a 2.09% increase in search time when compared to control cases.

Interruption type comparisons show math interruptions (M=122.32s, SD=38.66 s) lead to a slightly longer search time than mental rotation interruptions (M=118.17 s, SD=35.42 s), $t(20)=1.60$, $p=0.12$, Cohen's $d=0.11$.

Accuracy experiment 1

Approximately 78.5% of all targets were detected with no significant differences in the amount of targets missed between interrupted (Math Interruption: M=1.44, SD= 1.92; Mental Rotation Interruption: M=1.64, SD=1.03) and control cases (M=1.51, SD=1.55).

Math interruption + control case mean of target misses comparison: $t(19)=.93$, $p=.3$, Cohen's $d=0.04$

Mental rotation + control case mean of target misses comparison: t(20)=.1.09, *p*=.2, Cohen's *d*=0.09

Accuracy experiment 2

Approximately 90% of targets were detected with no significant differences in amount of targets missed between interrupted (Math Interruption: M=3.31, SD= 3.55; Mental Rotation Interruption: M=3.51, SD=3.59) and control cases (M=3.72, SD=3.57).

Math interruption + control case mean of target misses comparison: t(20)=1.69, *p*=.10, Cohen's *d*=0.11

Mental rotation + control case mean of target misses comparison: t(20)=.83, *p*=.41, Cohen's *d*=0.05

Foraging

Pre-interruption click-rates indicated that participants averaged at approximately 1.8 clicks every 5 seconds. In the 5 seconds following an interruption, click-rates dropped to an average of 0.5 clicks, and took an additional 5 seconds to return to their pre-interruption average.

Discussion

After accounting for the amount of time spent on the secondary task, the primary effect of interruptions on visual search tasks was a slower completion time. Although both types of interruptions led to longer search duration, there were no significant differences in regards to accuracy of target detection between the conditions. Similar to previous studies, we speculate that interruptions lead to an impaired memory for previously searched areas. This impaired memory consequently leads to slower task completion (Williams & Drew, 2017). An additional explanation for our results is that there is a speed/accuracy tradeoff caused by the interruption. When an interruption occurs, the observer sacrifices time in order to prevent errors from occurring.

Interruptions are thought to impact foraging in visual search by either prompting an early task termination or educing a prolonged search time (Wolfe, 2013). Either outcome can negatively impact task performance in the real world. Early task termination may cause radiologists to miss cancer nodules due to the search being ended too soon. In the contrary, a prolonged search can results in radiologists falling behind on work as a result of spending too much time on each case. However, very little research has been done regarding interruption-foraging interactions.

Our data suggest interruptions lead to a significant time delay in resumption of baseline task functioning. This provides nuance for the speed/accuracy tradeoff assumption for interrupted cases: perhaps observers sacrifice time in order to make up for what was potentially compromised by the interruption.

By quantifying the cost of interruptions on visual search, we can deepen our understanding of how visual attention and memory are affected by these disturbances. Ultimately, we hope this research will lower the rate of medical errors by shining light on the costs associated with interruptions.

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