Noisy Signals: Understanding the Impact of Auditory Distraction on Web Search Tasks

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ABSTRACT

More than half of all searches are now submitted on mobile devices, which can (and often are) used in various potentially distracting situations, such as travelling on a noisy train or when walking down a busy street. Research suggests that walking has negative effects on search performance and behaviour and that auditory distractions can impact on user input and affect perception of task duration. In this work we conduct a user study (n=16) using a simulated distracting condition to investigate how auditory distractions change perceived and objective search performance and behaviour. Our results suggest that noisy environments induce stress on users, causing them to feel additional perceived time pressure, leading to a reduced ability to identify task-relevant documents and a compulsion to finish the search task quickly.

KEYWORDS

mobile search; distraction; search experience; cognition; user study; experimentation

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1 INTRODUCTION

Since as early as 2016 the number of Google searches made using mobile devices exceeds that of desktop machines [3], meaning that such devices are now our primary means of searching the web. They are used by around half of all users for everyday Information Retrieval (IR) tasks such as searching for real estate, jobs and getting information about health problems and government services [14]. However, unlike "traditional" desktop machines, they are commonly used on public transport, while walking from place to place [8, 9, 13] or in social contexts [2] - all situations where there is the potential for significant auditory distraction.

Distractions encountered during walking on a busy street, driving, and using public transport can preoccupy users [11], reducing their effectiveness in interacting with a UI UI [1, 9] and resulting in a larger number of misspelled and underspecified queries [12, 13]. A large body of work has considered how distraction affects user input on mobile devices, including how attention is diverted from the interface when following a pre-defined, but otherwise uncontrolled, route through a city. This was found to cause significant impairment when compared with a "non-social laboratory condition" [11].

Recent work, in which participants were subjected to simulated conditions (a treadmill and pre-defined indoor route), investigated how ambulatory distraction (walking) affects web search [4, 5]. Participants in the distracted conditions were found to objectively perform worse than those who were not distracted and perceived increased time pressure and stress. Very little work has considered how another common type of distraction - noise - impacts on user behaviour for mobile tasks. The only work to date, by Hoggan et al. [7], investigated a number of novel interfaces, including a haptic interface and one based on auditory signals, for simple touchscreen typing tasks. Participants performed the tasks whilst on a noisy and bumpy subway and were found to perform progressively worse as the noise level increased.

When people use their devices in context they process auditory information more efficiently when relevant auditory and visual stimuli are presented from the same, rather than different, spatial locations [15]. More specifically, they can be distracted when audio and visual stimuli appear to be disconnected. Research from psychology suggests that sounds that have affective impacts can modulate time perception - those that are arousing and hard to ignore increase perceived task duration [10]. Studying the combined effects of auditory distraction and task completion will not only have key applied implications, but will also evaluate the how well users are able to recovery from auditory distraction, which is not well addressed [6].

In contrast to previous work, we consider how auditory distractions impact user performance for specific search tasks, as opposed to simple typing and button selection tasks, and on the participants' perceptions of this impact. To aid in both repeatability and realism, our studies involve a *simulated* context in which participants are exposed to a pre-recorded audio track of common loud and distracting sounds. The results for participants placed in this context are compared with results from those under exactly the same experimental set up but with no auditory distractions (a quiet room). As people frequently also use tablets to access the web on the go, we conduct experiments with both tablet and phone devices.

Our main research questions are:

- Do auditory distractions impact on search performance for common search tasks?

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- How do users perceive these distractions and are they aware of their effects on their own search performance, if indeed there are any?

2 METHOD

We conducted a laboratory experiment with 16 participants drawn from a large European University (a mixture of academic staff, support staff and post-graduate students), of whom 10 were male and who had a modal age range of between 25 and 30. There were two independent variables: the type of *device* (tablet or phone) and whether or not participants were subjected to simulated *auditory distractions*.

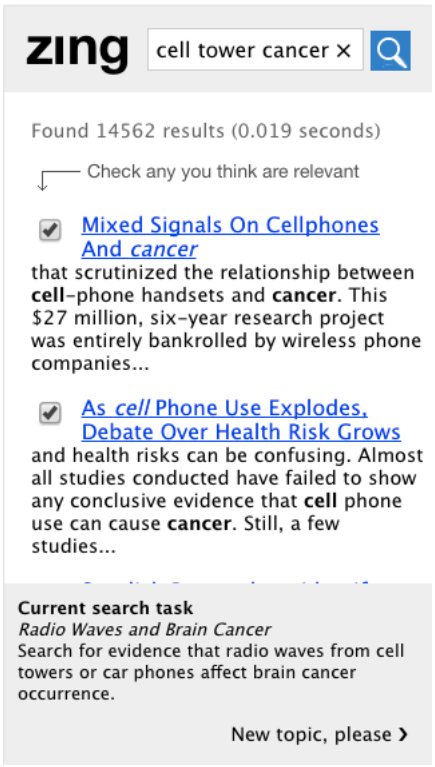

Figure 1: zing search interface on an Apple iPhone 5. Checkboxes used to indicate relevance.

We developed a simple mobile search interface named *zing*, shown in Figure 1, which mimics a standard SE interface by showing 10 links in descending order of relevance together with snippets for each. The interface allowed participants to enter search terms and indicate (via checkboxes) which documents they thought were relevant. It showed the current task (TREC topic) at the bottom of the screen and allowed participants to progress to the next topic at any time. The interface also prompted users to fill in pre- and post-topic questionnaires to survey their perceptions about the task and their self-assessed post-task performance, satisfaction, perceived time pressure and focus/involvement on the task. Half of the participants completed their first 2 topics on a phone, moving on to the tablet for their final 2 topics, while the other half began with the tablet.

We created simulations of typical auditory distractions using a dictaphone with a wind-protected boom microphone around a major UK city, capturing everyday sounds (i.e. trains, cars, road works, people talking etc.). The audio was synchronised, layered and composed into sequences using a piece of editing software (Adobe Audition CC 2017) and we created 4 sequences for each search activity. Participants in the auditory distractions group conducted the experiment under the same seated conditions as those in the baseline, however speakers were placed on either side of them through which the audio sequences were played continuously throughout the tasks. The volume of the speakers (and the computer playing the audio) was the same for all participants and, as task sequence was randomised, so too was the audio sequence experience by each participant for the 4 tasks.

We used a standard test collection: AQUAINT[1] together with the 50 TREC 2005 Robust track topics, of which 4[2] were randomly chosen from a subset of those which are neither too difficult nor too easy. Indexing and searching was provided by Apache SOLR[3]. Each participant was given the same 4 topics (tasks) in a random order with a per-task time limit of 15 minutes and alternated between the two *device* conditions. Participants were asked to imagine they wanted to learn more about the subject of each topic for a short report and were requested to select 3-5 documents they thought were relevant.

3 RESULTS

Before the experiment was described to participants, they filled in a short pre-study questionnaire asking them about their use of mobile devices and search engines as well as how difficult they would expect it to be to search on a phone or a tablet in various contexts, including in a noisy environment. All participants reported using a search engine and a smartphone several times a day and all but one stated they used their device to search the web at least daily. Half (n=8) reported using them at least daily on public transport and 9 said they used them daily in "in a noisy and distracting social situation (e.g. a pub or café)".

3.1 Pre-task perception

Before each task, participants filled in a questionnaire about their prior topic knowledge, their interest in it and expected difficulty (clarity of task, overall difficulty, difficulty in finding relevant documents, and difficulty in knowing when to finish). For the first three questions there was little variation between the two groups, with all participants being moderately interested in the topics (mean=3.12) but, on average, not very knowledgeable about them (mean=2.06) and clear on what they had to do (mean=4.19). All participants said they expected using a mobile device to search the web while sitting still to be easy, very easy or trivial, however 2 expected doing the same in a noisy environment to be difficult and none thought it would be trivial under such conditions.

As shown in table 1, there were some interesting differences by condition for the other questions. Participants in the group

[1]We removed duplicate documents in a pre-processing step, to provide a better and more familiar user experience.
[2]Topics 362, 367, 404 and 638.
[3]http://lucene.apache.org/solr/

Condition	Sitting (baseline)	Distracting
Overall difficulty	2.32*	2.73*
Finding rel. docs.	2.5	2.5
When to finish	2.9*	3.2*

Table 1: Mean pre-task difficulty responses. * indicates significant difference (t-test, $p < 0.05$).

subjected to the distracting environment expected the task to significantly more difficult than those given the baseline condition. They also expected it to be significantly more difficult to determine when they'd collected enough information for the task. However, despite this, there was no significance difference in how difficult the two groups expected it to be to identify relevant documents.

3.2 Post-task perception

Immediately after each task the interface presented participants with a post-task questionnaire (see Table 2 for selected questions).

#	Question
Q1	I felt time pressure when completing this task
Q2	I needed to work fast to complete this task
Q3	Overall, I thought this was a difficult task
Q4	It was difficult to find relevant information on this topic
Q5	It was difficult to determine when I had enough information to finish the task
Q6	It was important to me to complete this task quickly
Q7	While I was working on this task, I thought about how much time I had left
Q8	While I was working on this task, I thought about how well I was doing
Q9	I blocked out things around me when I was completing the search task

Table 2: Selected post-task questions.

As shown in Table 3, there were a number of significant differences in the responses between the two groups and some questions for which responses were, perhaps surprisingly, not different. Despite all participants being given the same amount of time for the tasks, it is clear from Q1, Q2, Q6 and Q7 (all significant differences) that those in the distracting audio condition felt under much more time pressure. Even so, they did not perceive the task to be any more difficult than those under the baseline condition (Q3) and did not find it any more difficult to locate relevant information (Q4). In agreement with their pre-task perceptions, however, they did find it significantly more difficult to determine when they had enough information to complete the task (Q5). It seems the considerable additional perceived time pressure made the distracted participants more concious and concerned about their own performance (Q8), even though they thought they were not significantly less able to block out the world around them (Q9).

Condition	Sitting (baseline)	Distracting
Q1	2.61*	3.49*
Q2	2.34*	2.68*
Q3	2.72	2.89
Q4	3.05	3
Q5	3.62*	4.14*
Q6	2.61*	3.83*
Q7	2.47*	3.19*
Q8	3.72*	4.47*
Q9	3.57	3.38

Table 3: Mean post-task questionnaire responses. * indicates significant difference (t-test, $p \ll 0.01$).

3.3 Task Performance

To objectively evaluate search performance, we rely on a number of metrics: the average number of hits (relevant documents) returned per search query; the mean average precision (MAP); the number of documents bookmarked per user per topic; the number of those that are relevant; the ratio of documents bookmarked that were relevant; the number of documents read per query; the average query length; and the average query duration per task. The results of these analyses are shown in Table 4.

Condition	Sitting (baseline)	Distracting
Hits/query	3.23	3.04
MAP	1.106	0.094
Bookmarks/topic	2.75	2.82
# relevant	1.82	1.21
(ratio relevant)	0.63	0.45
# documents read	1.59	1.2
# query terms	3.61	3.52
Query duration (s)	42	37

Table 4: Objective performance measures by condition.

Although none of the objective performance measures differed significantly by condition, there are a number of fairly large and interesting differences which, given larger sample sizes, may become significant. It seems that condition had little impact on the participants' ability to construct queries as both groups achieved similar numbers of average hits and MAP values. However, when we look at the participants' ability to identify relevant documents, it seems that the auditory distractions may have had an effect. Despite the fact that the "distracted" users actually bookmarked more documents per topic on average, fewer of these were relevant than those bookmarked by the participants in the baseline group. This means that, on average, the baseline group were able to identify a relevant document 65% of the time, while the other group only managed this is 45% of cases. The baseline group read more documents, submitted longer queries and spent a little longer querying than the other group. Linear modelling indicates that both Q4 and Q5 are significant predictors of task performance (in terms of number of relevant documents bookmarked).

4 DISCUSSION AND CONCLUSIONS

In this work we sought to investigate how everyday auditory distractions commonly experienced by mobile searchers (e.g. noisy

public transport, pub and café environments, roadworks, etc) impact on their searches. We conducted a user study with a total of 16 participants, 8 of whom were seated in a quiet, distraction-free environment (the baseline group), while the other 8 (the distracted group) were subjected to pre-recorded audio tracks to simulate such environments. The participants were given a set of 4 different search tasks to perform on the mobile devices and were asked to complete pre- and post-task questionnaires for all 4 tasks, which were presented at random to mitigate ordering/fatigue effects.

Our results suggest that the auditory distractions had a number of significant effects on the perceptions of the people in the distracted group. Mostly notably, the conditions seemed to induce a feeling of time pressure, even though it was never necessary to impose any kind of time restriction on any of the participants. The distracted group felt significantly more rushed and felt they had to complete the task more quickly than those in the baseline group, although strangely this did not appear to make them consider the task to be any more difficult. This result ties in with the work of Noulhiane et al. [10] who found that certain distracting sounds have the ability to increase perceived duration and, thus, perceived task duration. It may be that this result is also due to the somewhat irritating nature of the disruptive sounds and may, therefore, be due to the wishes of participants to complete the tasks quickly so that they can minimise the amount of time they are exposed to the spatially-discordant stimuli [15].

In keeping with their pre-task perceptions, the distracted users felt - in comparison with the baseline group - that it was significantly more difficult to determine when they had enough information to complete the task, although did think it more difficult to find relevant information. Despite this, the objective performance results suggest that that it was indeed more difficult for the distracted users to ascertain whether or not a document was relevant, as they had lower success in determining relevance, albeit not significantly so. This may be because they spent less time on the tasks and read fewer documents, likely due to the additional perceived time pressure. However, the level of distraction from the audio may also have made it more difficult for them to concentrate on what they were reading and/or recall what they had already seen.

Comparison with the results of Harvey and Pointon [4, 5], who investigated distracting in the form of walking on a treadmill and navigating an obstacle course, suggest that auditory distractions are different from ambulatory ones. While the effects on querying performance are not so great, auditory distractions induce a much greater increase in time perception (and corresponding stress caused) and a decrease in the ability of participants to evaluate the relevance of documents.

4.1 Future Work

This research provides us with an initial understanding of the impact auditory distractions can have on search, however, there are a number of potential possibilities for future research to build on this. Although many of the differences between the groups in terms of perception were significantly different, the differences in objective performance, although at times seemingly quite large, were not significant. This may be a result of the relatively small cohort size and, therefore, an obvious extension to this work would be to increase the number of participants. In addition, more specific analyses could be performed to try to determine whether or not there are specific sounds that are more distracting than others and whether or not there is a fatigue effect. Alternatively, as some participants suggested, the opposite may be true - initial expose to the audio is distracting, however, after some time, people grow accustomed to the stimuli and are able to "tune it out". Finally, it may be interesting to experiment with a third, more naturalistic, condition (like that used in the work of Hoggan et al. [7]) in which participants perform searches out "in the wild". Although, unlike the work presented here, the obvious issue with this is that it would not be possible to guarantee that all participants are exposed to the same stimuli, making any generalisation of results difficult.

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