Investigating information seeking in physical and online environments with escape room and web search

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Abstract
Searching and interacting with information is one of the most fundamental behaviours of human beings – something that takes place in both online and physical environments. Yet, most studies of information interaction have focused on only one of these sides. This work aims to connect them by investigating one's information interaction behaviours in different physical and online contexts as well as different types of tasks. During *Web search* (online searching) and *Escape Room* (physical searching), 31 participants' behavioural data during web search (online searching) and escape room (physical searching) were collected through eye-tracker, web browser logs, and wearable video recorder. Analysis of the behavioural data suggests that individuals have a *preferred search strategy* that they adopt across different tasks and environments. The behavioural pattern, however, was found to be affected by the task type (e.g. problem searching vs exploratory search) and the way information is structured within the environments.

1. Introduction

The way people seek for and interact with information has been examined by considering diverse factors affecting the behaviour such as task type and complexity [1–3], cognitive styles [4,5], and behavioural patterns [6]. At the same time, studies on individuals' exploratory behavioural patterns have suggested dichotomic traits in different contexts. In past studies, individuals' mobility patterns were categorised into either *returner* or *explorer* [7]. Along the same lines, people were found to exhibit their web navigation style as *Web returner* or *Web Explorer* [8]. A study with functional magnetic resonance imaging (fMRI) experiments found that people use the same brain structures relating to navigation behaviour with both online material and physical objects [9].

Previous studies on behavioural patterns in exploration, however, have not found the extent to which individuals' online and physical behaviours are associated and why they are related. Our focus in this work is on identifying and comparing the same individuals' search behaviour in online and physical spaces. To investigate these interconnections, we conducted a study involving 31 participants that went through two sessions: *Escape Room* game with two different tasks to see how people solve spatial search problems; and *Web Search* with two types of tasks to observe how the same

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individuals work through online search problems. We first gained a qualitative understanding of how users investigate information in the search process via video and log data analyses. Then we identified participants' behavioural patterns based on their exhibited strategies for addressing the given tasks. Analysing users' behaviour in tasks and how they react to the different tasks as well as different environments sheds light on the similarities (and differences) of human information seeking behaviour in diverse settings and paves the way for creation of enriched models of human information behaviour.

Hence, the main objectives of this work are as follows: (1) to study the interconnections between online and physical search tasks and (2) to present a newly designed *Escape Room* experiment to study individuals' behaviour in physical search tasks.

The structure of this article is organised as follows. Section 'Related woks' provides the existing literature review on searching behaviours in online and physical spaces and research questions (RQs) this study is answering to. Section 'Methods' describes the research method, and section 'Results and findings' presents the results and findings. Section 'Discussion' discusses on the findings, followed by section 'Conclusion' describing the conclusion and future work.

2. Related works

We begin by clarifying our use of terms such as *searching, seeking*, and *information behaviour*. We are following the traditional view of these terms, as perhaps most notably depicted by Wilson [10]. Here, *information behaviour* is an all-encompassing concept that includes *information seeking* as a subset, which in turn contains *information searching* as a prominent part. In the work reported here, we are primarily considering one's search behaviours, with implications on their seeking and overall information behaviours.

When it comes to the concept of information seeking, the superset of searching, Bates [11] suggested the *berrypicking* approach to information seeking behaviour, which uses the analogy of a person picking berries in a forest. The approach viewed an information seeker moving through an information space, gathering chunks of information, and seeking cues that help to navigate the user through a series of decisions. This model highlighted the *dynamism of needs* during the search instead of focusing on the actual activities. These activities refer to how individuals interact with the information environment. Similar to *berrypicking*, the information foraging theory (IFT), suggested in [12–14], was inspired by the analogy between the foraging behaviour of animals looking for food and that of humans visiting information patches and gathering fruits of found information. The theory is particularly important because it attempts to incorporate information search behaviour with other types of humans' (even animals') behaviour using the theoretical analogy, which is supported by empirical experiments. For instance, Chi et al. [15] applied the concept of *information scent* in order to model users' information needs and their responses on the web. In addition to *berrypicking* model, IFT highlights the relationship between individuals' searching strategy and their economic preference. Savolainen [16] examined how berrypicking and IFT represent two unique and related ways to study exploratory search behaviours, with berrypicking referring to changing information needs as the main motivator for information searching, while IFT focuses on the role needed for performing a task as a main trigger of information seeking.

Regarding online search behaviours, Aula et al. [17] examined participants' search patterns on fixed search engine results pages (SERPs) using eye-tracking data. They categorised participants into *economic* or *exhaustive* evaluation styles based on their initial approach to evaluating search results on web pages. While *exhaustive* evaluators looked at more than half of the search results for the majority of the tasks, economic evaluators spent relatively less time, and effort in examining search pages before the first click. When most of the results in the SERPs are relevant, the searching time of the economic evaluator is significantly shorter than *exhaustive* evaluators. In a similar way, the *depth-first* and *breadth-first* strategies have been suggested by Klöckner et al. [18] to understand individual differences. These notions of differentiating people's search behaviours are quite relevant to our work here, and therefore, we will revisit them as we propose our approach later.

Several previous studies addressed individuals' geographical trajectories and exploration within various viewpoints. Gonzalez et al. [19] gathered 100,000 people's locations via the global positioning system (GPS) sensors on their phones and correlated their mobile trajectory with temporal spatial regularity, characterising each individual's time-independent travel distance and a significant probability to return to a few highly visiting places. Wang et al. [20] and Cho et al. [21] used similar data of trajectories and communication records of mobile phone subscribers to find the strong similarity between individual's mobility pattern and their social connectedness, suggesting that human mobility could be a good predictor for the new link formation. Shmueli et al. [22] and Singh et al. [23] investigated places where different types of personal consumption are happening, coming up with spatio-temporal traits such as *exploration, engagement*, and *elasticity*. More specifically, when it comes to physical exploration and information searching, Choi et al. [24] found the significant associations between geo-exploration aspects in a physical space and certain search factors in an online

environment via analysing GPS and web-log data. The results showed that the location loyalty and the diversity in the real world were related to the diversity of query generation and novelty of retrieved information.

An ongoing debate in the cognitive psychology literature concerns the process for search in a variety of domains. One argument is that the mind incorporates numerous autonomous and domain-specific neural modules [25,26], each of which is designed to manage a specific class of problems. On the other hand, evidence is accumulating that supports the existence of domain-general cognitive processes, specifically, the search process as the means for problem-solving. When it comes to search process, which is of interest in this article, Hills et al. [27] discovered behavioural tendencies over different search spaces – a spatial search and a lexical search task – to suggest the priming effect on the domain-general search process. Through the comparable experiments of spatial search, which was simulated on a PC screen, and lexical search with letter sets, they found that the person who conducted the spatial search in a clustered space tended to continue searching longer in each letter set, which indicates that person transferred his or her behaviour during one task to a superficially dissimilar task. The general concept of exploitation and exploration in terms of searching behaviour in different contexts are summarised by Hills et al. [28].

2.1. RQs

It should be clear from the related works described above that (1) many theories and models pertaining to information seeking/searching are inspired by people's general exploration behaviours; and (2) there seems to be some connection between an individual's behaviours in online and physical environments around search. Inspired by these insights, in this article, we investigate the information behaviour of users doing search tasks in online and physical spaces. Specifically, we pose the following three RQs.

1. What are the behavioural patterns in online and physical searches, specifically regarding information evaluation approach?
2. To what extent, if any, does physical search behaviour relate to online search behaviour?
3. To what extent, if any, do task type and the related characteristics affect online and physical search behaviour?

3. Methods

In order to observe individuals' online search behaviour, we asked participants to complete two kinds of tasks for 20 min each: Task 1 asks to find answers to 10 'A Google a Day' (http://www.agoogleaday.com/) questions; and Task 2 requires an exploratory search to write a report about a given topic such as 'health information about type 2 diabetes'.

When it comes to the physical search, which, to the best of our knowledge, has not been investigated in experimental settings regarding information behaviour, we adopted a game named *Escape Room*, to understand how people interact with information in physical space. In this adventure game, players solve a series of puzzles using clues, hints, and strategies to complete the given missions. We designed an *Escape Room* game dedicated to this research and conducted a user study combining it and *Web Search* tasks as shown in Table 1.

In *Escape Room*, one enters a room and needs to unlock five locks (red circles in Figure 1) in a particular order to finish the game (Details are described in Appendix 1). Note that while there are five subtasks given to the participants, we analysed first two ones (*book task* and *movie task*) only because not all participants were able of finish all of them. The first one, *book task*, is to find a specific page in a book that contains information the question asks (books are displayed

Table 1. Session workflows for Escape Room and web search tasks.

| Session	Procedure	Description	Time
Web search	Introduction	Introduce the laboratory session and set up the task PC (eye-tracker and video recording).	5 mins
	Task 1	Problem-solving: finding answers to A-Google-A-Day questions.	20 mins
	Task 2	Exploratory search: write a report about a given topic.	20 mins
	Wrap-up	Additional surveys and wrap-up.	10 mins
Escape Room	Introduction	Introduce the escape game and put a wearable video recorder on.	2 mins
	Game play (Task 1–5)	Participants play an Escape Room game, solving problems and finding clues in a room.	20 mins
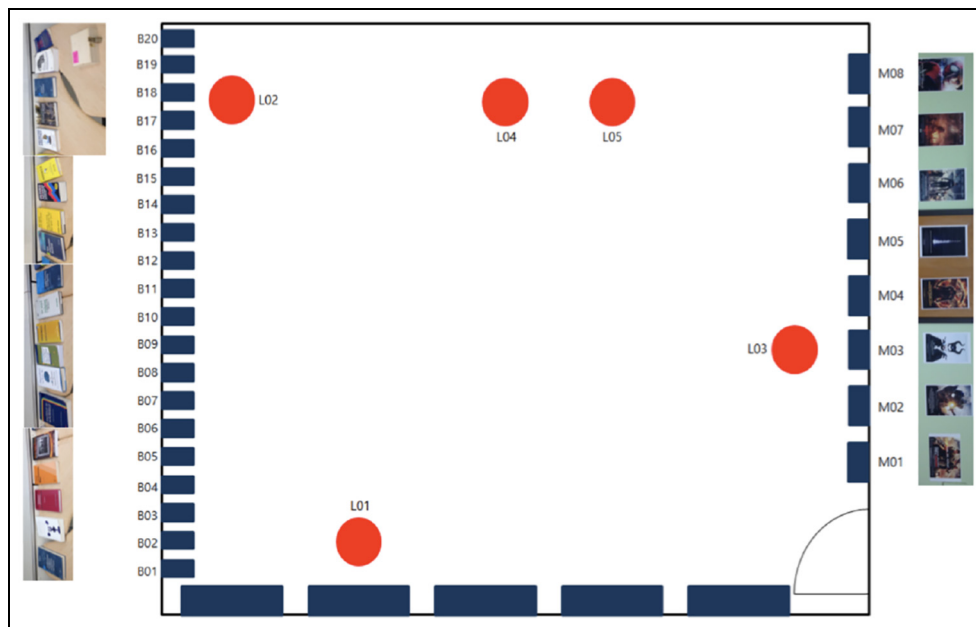
Figure 1. Escape Room game: Participants enter the room from the door in the bottom right corner of the picture. The mission is to decode the locks (red circles) in a particular order. The relevant information for each task is on the left wall (*books*) and right wall (*movie posters*).

on the tables next to the wall). In *movie task* one needs to find an actor's name from a movie poster that meets the question's criteria among the posters on the right wall.

Note that we had designed the book task and movie task to encourage users to use one particular strategy over another. For instance, in the book task, there were 20 books spread over the tables in front of a user. The researcher conducting the session would give the participant a tip, saying, 'Multimedia search is a sub-topic in information retrieval', implying that the best way to locate relevant information is to first select books that are associated with information retrieval. The *movie* task had different setting. The participant first needed to locate a movie poster of a film produced by particular studios (Paramount Pictures and Warner Bros. Pictures), yet, the letters on the posters were too small to read from afar. Therefore, it was natural for a person to start reading the poster closest to them and to go closer to the information to understand it in detail.

3.1. Participants

Thirty-one participants (15 male and 16 female) were recruited via targeted email and social network channels such as the Facebook group restricted to Rutgers university members. The participants were invited to an academic building to conduct *Web Search* and *Escape Room* tasks. After completing all study sessions, each of them received $100 in cash. They were engaged in diverse majors such as Information Technology, Business, Computer Science, and Psychology.

3.2. Data collection

Participants' information seeking behaviour was observed via several devices. During the *Escape Room* session, participants were asked to wear a pair of Google Glasses with an embedded video recorder.

During the *Web Search*, we logged all of the URLs the users visited during sessions, as well as activities such as keystrokes and mouse scrolls. We also recorded what was occurring on the screen and the users' eye gaze during the tasks.

3.2.1. Information patch. When Bates [11] depicts an information seeker moving through an information space in general, she assumes *information chunks*, between which the seeker wanders and moves looking for information. IFT [14,29] uses the term *information patch* to depict the documents, or web pages, that the user visits to consume the information from
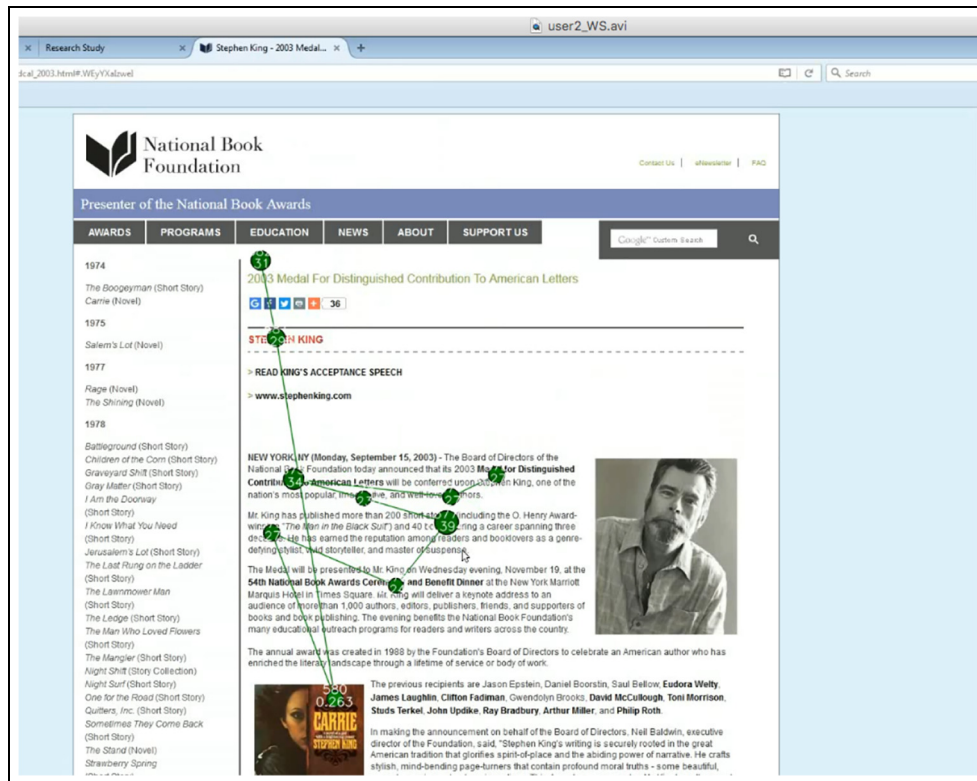
Figure 2. Video captured during web search tasks.
Green circles represent the user's area of interest, or eye gaze, along with timestamps and the order.

that patch. More specifically, the task environment of an information forager has a *patchy* structure [30]: information that a person looks for to meet her needs may reside in piles of paper documents, file cabinets, bookshelves, libraries, or in various online documents.

In this study's web searching task, the information patch refers to (1) SERP and (2) each web page that the user visits. In the Escape Room, an information patch can be a book or a poster that can be delivering information for the participants to examine to solve the provided quizzes.

3.2.2. Web search. Aula et al. [17] defined two kinds of search strategy – 'economic' and 'exhaustive' – based on whether a user scanned less than or more than half of the visible results before making a decision to click. Inspired by this measure, we categorised the participants' behaviour into *exhaustive examination* and *economic examination. Economic examination* refers to the case in which only the top *one* or *two* results were inspected before the first click. Otherwise, we defined it as an *exhaustive examination*.

To understand and identify participants' web searching behaviour, the web search log and recorded screen video during the search tasks were transcribed and coded. Web search logs were captured through a browser plug-in. Video data includes normal screen capture as well as eye gaze data. While normal screen capture represents users' interaction, such as mouse cursor movement and keystrokes on the web browser and other computer systems, the eye gaze data are annotated with circles, increasing along with dwell time for a particular area of interest and timestamps. The application for the eye tracker provides a video file that combines both of the screen capture and eye gaze data per one user's session (see Figure 2), and the capture web searching behaviour were played and replayed several times to examine their behavioural pattern regarding the online exploration.

3.2.3. Escape Room. The participants' searching activities via their sight movements were captured by a video recorder embedded in the provided glasses. While the video recorder could not capture all exact sight movements, it was enough to judge their intentional behaviours and cognitive status. Two trained coders created code schemes derived from

Table 2. Coding scheme of Escape Room study.

Code	Description	Type
Looking around	Looking and moving around the room	Point
Scanning books	Scanning books without movement	Point
Scanning movie posters	Scanning several movie posters without movement or with slow movement	Point
Passing by a book	Passing by each book	Point
Book	Visiting a book with starting and ending points	State
Movie poster	Visiting a movie poster with starting and ending points	State
Reading questions	Reading the task questions at first time	State
Re-visiting questions	Re-visiting the questions during solving tasks	Point
Dealing with a lock	Trying to unlock the lock	State
Calculation	Calculation to solve the *Task 2*	State

significant behaviours observed during this session (see Table 2). Based on these code schemes, the coders manually recorded participants' time-stamped ethograms associated with the information patch map (see Figure 1) using a video coding software (Boris [31]). In the code scheme, *type* means the attribute of time for the code; *state* indicates existing time duration and *point* means the moment of action.

As described earlier, during the physical search, we asked the participants to solve five questions to unlock five safes, demanding to accomplish several tasks, including exploring books, movie posters, and research posters.

While we collected participants' behavioural data of exploring and investigating the information patches provided in those tasks, we decided to code and analyse the data from only those associated with searching books (book task) and finding answers in movie posters (movie task). One of the reasons behind this decision is that out of the 29 participants whose data were captured by the wearable video recorder, 25 people were able to finish only up to the second quiz that requires one to find an answer from the movie posters and the other answer from the research posters. More specifically speaking, some participants seemed to be confused and did not understand the question related to research posters. We posit that undergraduate students might not be familiar with the structure, and the context of specific research posters on information retrieval and information searching behaviour studies. After doing the first two tasks, some participants started to struggle with finding hints and answers and ended up failing to solve that problem. For this reason, we did not analyse this part of the physical search data and covered only the results and analysis from the book task and movie task in this article.

4. Results and findings

We start by reporting and discussing the results with *Web Search* first, followed by the *Escape Room*. After reporting the results, we will attempt to look through any behaviour patterns similar or dissimilar between these two contexts.

4.1. Descriptive analysis

In web search session, participants were supposed to solve 10 questions in *Task 1*. While five participants solved all 10 questions, one participant was able to answer only one question. Note that there is no objective success or failure for *Task 2*, which is an exploratory search task.

In escape room session, 29 out of 31 participants' recording were valid for the analysis due to technical issues on the recording device. While there were five tasks that the players needed to accomplish in the escape room game, less than half (42%) of the participants (13) completed the total five tasks, and four participants were able to finish only the first task.

4.2. Evaluation of web search behaviour

Note that web search session consists of two tasks that have different characteristics. For instance, *Task 1* is a fact-finding search task, which is assumed to have the least complexity, requiring participants to use basic searching skills. For *Task 2*, however, a user needs to spend enough time to understand the topic and requirements, construct necessary knowledge through Web exploring, and build a narrative that convinces a potential audience.

By observing and annotating users' behaviour through recorded video and eye gaze data, 31 participants were categorised into *exhaustive* evaluation and *economic* evaluation types for each task. Participants might have different

Table 3. Number of participants for evaluation type during *Task 1* and *Task 2* in Web search.

Behavioural patterns		Web search: Task 2		Total
		Exhaustive	Economic	
Web Search: Task 1	Exhaustive	13	0	13
	Economic	6	12	18
Total		19	12	31

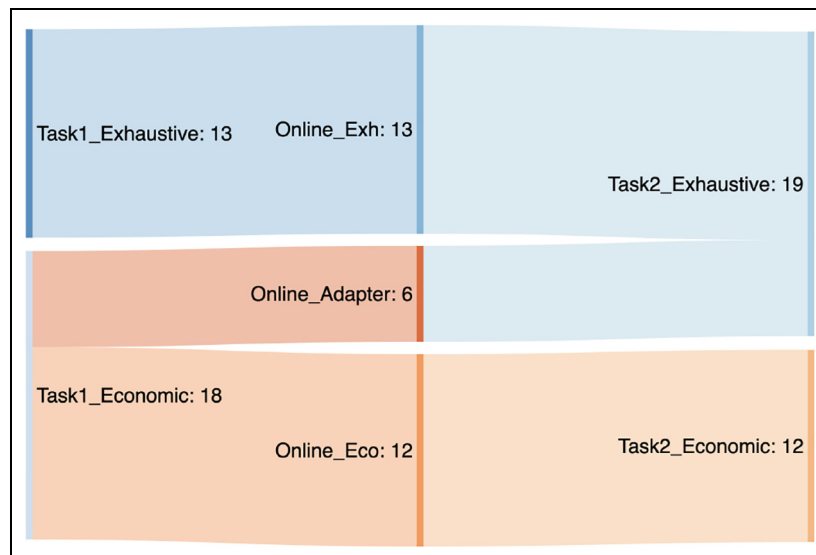**Figure 3.** Behaviour change between Task 1 and 2 of Web search: (1) *Online_Exhaustive_Evaluator*: 13 participants who used exhaustive evaluation both in *Task 1* and *Task 2*; (2) *Online_Economic_Evaluator*: 12 participants who used economic evaluation both in *Task 1* and *Task 2*; and (3) *Online_Evaluation_Adapter*: 6 participants who adapted, or changed, their evaluation behaviour based on the task type.

evaluation strategies for different search tasks, such as between *Task 1* and *Task 2*, as shown in Table 3. During *Task 1* of the Web search (the problem-solving task), 13 participants adopted exhaustive evaluation, while 18 used economic evaluation. During *Task 2* of the Web search (the exploratory search), 6 users used the exhaustive evaluation approach, while 12 used economic evaluation.

A χ^2 test of independence was performed to examine the relation between these behavioural patterns; $\chi^2(1, N = 31) = 11.47$, $p < 0.05$, indicating distribution of participants' evaluation behaviour in *Task 1* and *Task 2* are significantly different and the behaviour is related to the task. It suggests that economic evaluation was preferred in *Task 1* and exhaustive evaluation was preferred in *Task 2*, possibly indicating the effect of task type on the evaluation strategy. These findings are along the same line with previous studies. Lorigo et al. [32] found the effects of question types – informational (e.g. *Who discovered the first modern antibiotic?* and navigational search questions (e.g. *Find the page displaying the route map for Greyhound buses*) – on search and evaluation behaviour. They found that the general time spent to solve the questions and pupil dilation were influenced by whether the search task was informational or navigational.

However, there was a group of participants who kept their search behaviours the same even in a task in which the opposite behaviour was preferred. For instance, 12 participants who adopted economic evaluation to quickly solve the questions in *Task 1* adhered to economic evaluation in *Task 2*, opening the top first or second result page in the retrieved list without reading abstracts below them. This finding indicates the existence of strongly preferred and habitual evaluation strategies during online search.

Based on the observation above, participants' evaluation behaviour in online space can be explained as in Figure 3.

Table 4. Evaluation type during Book task and Movie task in Escape Room.

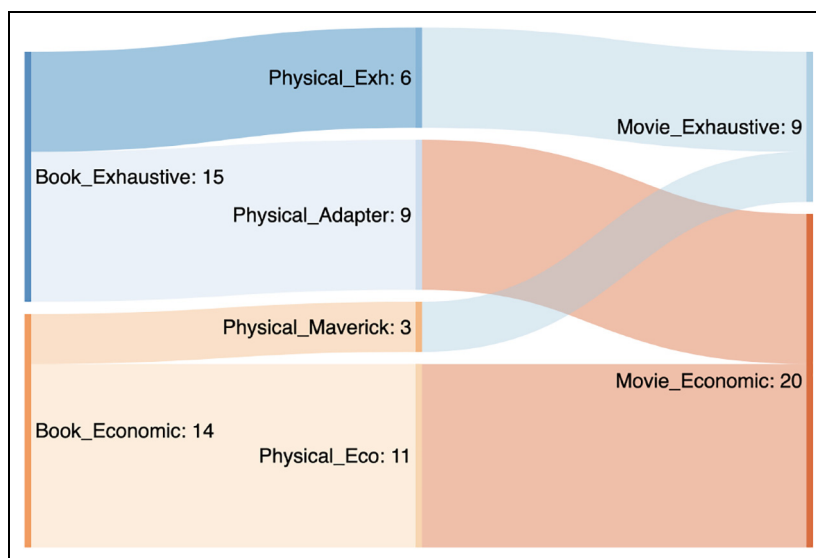| Behavioural patterns		ER: Movie Task		Total
		Exhaustive	Economic	
Escape Room: Book Task	Exhaustive	6	9	15
	Economic	3	11	14
Total		9	20	29

Figure 4. Four types in the middle of the figure describe the behaviour change between book task and movie task of ER: (a) *Physical_Exh(austive_Evaluator)*: 6 participants who used exhaustive evaluation both in Book task and Movie task; (b) *Physical_Eco(nomic_Evaluator)*: 11 participants who used economic evaluation both in Book task and Movie task; (c) *Physical_(Evaluation_)Adapter*: 9 participants changed their evaluation behaviour based on the task type or environment; and (d) *Physical_(Evaluation_)Maverick*: 3 participants who used economic evaluation in book task and exhaustive in movie task.

4.3. Evaluation of Escape Room behaviour

With two participants' observation data missing due to the device failure, 29 participants were categorised into *exhaustive* evaluation and *economic* evaluation type in tasks of Escape Room game. Participants might have different evaluation strategies for different search tasks, identifying the patterns between *Book Task* and *Movie Task* as shown in Table 4.

While conducting the book task of the Escape Room game, 15 participants adopted exhaustive evaluation, while 14 used economic evaluation. During the movie task of the Escape Room game, 9 participants used exhaustive evaluation, while 20 used economic evaluation. Participants' evaluation behaviour in physical space can be explained as shown in Figure 4.

Even though the differences were not found to be statistically significant, annotated behavioural pattern of examining information in a physical space (Escape Room) indicated that individuals might general preference over different tasks, similar to what we observed in online search tasks. As we have mentioned in the Methods section, the book task and movie task are designed to encourage users to use one particular strategy over another through the way in which information patches are displayed: while books are widely spread over the tables and easy to read the titles from a distance, words in the posters are too small to tell what it says from a distance, requiring the participants to come closer to them. It is natural to expect a participant to look through the series of books to get exposed to relevant information patches through an exhaustive examination. Likewise economic examination tends to work better for movie task, starting to look at a particular poster first to read and understand the details.

In that regard, participants of *Physical_Adapter* in Figure 4 are thought be individuals who observed the information environment in different tasks of *book* and *movie* and adapted their searching behaviour accordingly. In the mean time,

Table 5. Groups based on the behavioural patterns in online (Web search) and physical search (Escape Room).

Behavioural patterns		Physical search				Total
		Exh.	Eco.	Adapter	Maverick	
Online search	Exh.	4	5	2	1	12
	Eco.	0	4	6	1	11
	Ada.	2	2	1	1	6
Total		6	11	9	3	29

Physical_Maverick showed an interesting behavioural change: an exhaustive evaluation before reading the information in *movie*. This might be an action without conscious intention, or something that happened after exposure to the Escape Room environment.

In short, we found that the task type had an effect on people's information search behaviours in physical search setting just as they did in the online search.

4.4. Behavioural patterns over online and physical space

Comparing the behavioural patterns in online space and physical space, participants out of 29 valid samples were identified into groups shown in Table 5. While exhaustive and economic type are the main behavioural patterns in online search, we can observe maverick emerging in physical search and more people are changing the strategy in physical space to different tasks (9 of physical adapters). Detailed discussion will be covered in next section.

5. Discussion

5.1. Individuals' behavioural patterns in online and physical search

As an important aspect of searching behaviour, we investigated the ways in which people read and evaluate information before they look into the details (evaluation strategy). First, analysis of eye-tracking data from *Web Search* and video data from *Escape Room* identified related behavioural patterns in online and physical searches. While the number of participants in each behavioural group does not necessarily mean the popularity of the patterns in the general population, the analysis found that there is a significant number of participants who showed the same evaluation strategy even in different circumstances. In other words, they were either *exhaustive evaluators* or *economic evaluators*, and they stuck to that trait despite differences in the contexts (physical or online). Even in a situation where a task by nature demanded a particular approach or strategy to effectively accomplish the task, some participants kept their preferred behavioural pattern. This provides more weight to the existence of a common algorithm we live by Christian and Griffiths [33], or a central executive as a search process (CESP [34]). Hills et al. [34] discovered individual behavioural tendencies over different search spaces – a spatial search and a lexical search task – indicating people transferred their behaviour for one task to a superficially dissimilar task. What we found in the study reported here is in line with their findings, but we are able to push the boundary of that knowledge by incorporating both physical and online contexts.

5.2. The effect of task type and environment on information behaviour

Many scholars have studied the effects of task type to task performance and user behaviours [35–37]. More recently, Liu et al. [38] showed how tasks with different goals can influence people's intentions and behaviours. Specifically, they argued that to better understand users' Web search behaviours, one need to look at multiple, connected aspects of task facets (e.g. task goal and task difficulty) and their relations to the users background and motivations. Similar arguments have been made by Mitsui and Shah [39,40]. Where most of these studies lack is their ability to connect the fundamental human behaviour to the search behaviours in different domains and situations. That is one of the objectives for our work here (RQ3).

While the aforementioned finding suggests that a person adopts one search process in general, some behavioural groups were found to adjust their strategy, or approach, to the given task and information environment. Even when a person tends to have an innate or habitual strategy to an information problem, it should be considered that the task type affects how to view, access, assess, and accumulate the knowledge during the task. For instance, the tasks that are

conducted in user studies in information seeking and retrieval are categorised into several types such as *factual task, exploratory task*, and *abstract task*. Each of these tasks shows differences in several aspects. While a factual task (Task 1 in *Web Search*) is easiest in terms of complexity, an exploratory task (Task 2 in *Web Search*) is relatively complicated in that it demands a user to interpret the information she encounters and accumulates to create her own understanding, findings, and conclusion.

5.3. Information environment and exploratory behaviour

The work described here found a relationship between the way in which information is structured and the corresponding exploratory behaviour undertaken. Note that among the users who changed their behaviour, no one changed from an economic evaluator in *Web Search* to an exhaustive evaluator in *Escape Room* (see Table 5). This can be explained with two points. First, this might be caused by the environment the participants were engaged in: online versus a physical space. During online search, more specifically on the desktop in this work, participants had a relatively small area (PC monitor) to focus on while investigating information to accomplish the given tasks. In general, users can look at and investigate different areas on the (relatively) small screen using little effort to move muscles such as the ocular muscle, which controls the eye gaze, and muscles in the fingers and/or hands that control mouse scrolling and keystrokes (i.e. Ctrl + F to find a particular word).

Second, when it comes to layout, online information is usually designed such that *information scent* [15,41] is properly delivered to the users, providing a low-effort way to trace and understand the information. On the other hand, physical search requires relatively more of the user's time and effort. For instance, in the Escape Room situation, a participant was supposed to at least move her feet to reach the information patches, physically grab the books to open up and look into pages, and sometimes walk between areas in the room to complete several tasks. Moreover, in our everyday life as well as in the Escape Room setting, information scents are not considered in the same way they are online. While we believe Human processor model proposed by Card et al. [42] depicts how an individual interacts with online environment, the results from this work indicates that it does not suffice when considering information seeking across physical and online environment. Even when we see a relative stable clustering of evaluation behaviour (exhaustive vs economic), the clusters broke down into smaller components once we consider different levels of physical effort and the environmental context, suggesting the need for further refinement to the Card model.

5.4. Limitations of the research

First, limitations of this work include the small, relatively homogeneous sample, which might show similar searching behaviour. User studies with a small number of participants can be quick to conduct, with regard to recruiting subjects, operating experiments or performing analyses to address RQs but the interpretation of the results is difficult to transfer to the larger sample in general. Moreover, the fact that all participants of this dissertation are undergraduate students at the same University can add to a selection bias problem.

In general, the study results could have been more valid if two experimental conditions as well as task types in each condition were rotated.

When it comes to *Escape Room*, even though we had tested the experiments several times, there were still points that can improve the quality of study. For instance, in the case of the first *Book* task, participants were supposed to pick relevant-looking books to start searching information for solving the question. An instruction to the first question was provided in the problem sheet, but the extent of individual participants' understanding of the intention of the task is in doubt.

The investigating of online behaviour during online search and physical search is based on the assumption that examination on the results page *Web Search* and the corresponding behaviour of searching books is comparable. However, while search results from Web search engine provided a list in the order of relevancy, the placed books in *Escape Room* had nothing to do with the relevancy to the question: the books were randomly placed, and only four books that cover the relevant topic to the question were placed and there were other books between them.

6. Conclusion

In this article, we presented our work that investigated behavioural patterns in online and physical searches. We conducted a newly designed *Escape Room* experiment to study individuals' behaviour in physical search tasks. Our analysis of their information evaluation strategies showed the identified behavioural patterns in online and physical searches. The results suggest that individuals have a *preferred search strategy* that they adopt across different tasks and environments.

The behavioural pattern, however, was found to be affected by the task type and the way information was structured in different environments.

To the best of our knowledge, this research is the first of its kind that aims to investigate physical and online search behaviours of an individual through the lens of a fundamental human trait, namely, economic and exhaustive behaviours. It expands the theories and models of human behaviour on information search and interaction. For instance, the IFT [12] assumes individuals' rational economic system regarding cost and benefit when moving between information patches, but it analyzes these patches in a specific domain (e.g. online information). The work reported here extends that to physical spaces. Several of the past works on information behaviour have been limited to one or the other forms of information interaction – either in online world or in physical spaces. The presented work attempted to bridge those with interesting insights that could help expand those models of information behaviours with more focus on humans interacting with information, and fewer assumptions about where those interactions happen.

This research also focused on how external factors from the environment affect users' information exploration. However, this study suggests that individuals' personal preference can affect searching strategy. The fact that this phenomenon appeared in physical search suggests that we should consider physical and physiological factors when studying people's information behaviour. The findings show the value in interdisciplinary examination by connecting theories and models of Information Science to Experimental Cognitive Psychology and Behavioural Science.

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Appendix 1:

Escape room

In the game room, a participant needs to explore and search first to locate possible clues that provide following clues towards finding the key to escape that room. Given that there are several different things that can be suspected to contain a clue, a person needs to judge the relevance of each thing as to whether to invest his/her time and effort. All his or her activities were recorded by the wearable video recorder.

Figure 5 shows the escape room set up in a classroom.

The introduction to the game and tasks used in the preliminary study are as follows.

Figure 5. Escape Room game. Participants are supposed to search books (left bottom), posters (left top), and movie posters (right bottom) to unlock boxes presented in the room (right top).

The Escape Room Story:

A Professor named Tim Murphy is missing. You have entered his office to track possible clues he left, but you are also locked in his room. You need to keep accomplishing tasks until you get the final key.

- Task 1: 'Multimedia search' is a sub-topic in information retrieval. Find the page of the chapter of 'multimedia search' in a book. Use this page number to open the 3-digit lock.

There are four books related to information search and retrieval in the room. The participant is expected to pick some books and look at the table of contents of each book to get the page number, which is 207. Participant will unlock the 3-digit lock with this number and see the next task.

- Task 2: Find the poster of a movie that was presented by Paramount Pictures and Warner Bros. What is the first name of the hero of that movie? Then, find a research poster in which the first author's name is the same as the actor's first name. (1) Find out the last name of the first author. (2) Find how many undergraduate students participated in the experiment outlined in that research poster.

- The first two letters in the answer are the initials of the author's first and last name. Next, three digits are the square of the number of undergraduate participants. Use the answer to unlock the 5-letter lock (_ _ _ _ _). For instance, if the author is Tim Murphy and 20 undergraduates were involved in the experiment, the answer is TM400.

Among the movie posters there is one of *Interstella*, one of whose stars was *Matthew McConaughey*. And among the research posters, there is one poster written by a researcher named *Matthew Mitsui*. 20 undergraduates participated in the study presented in his poster, so the answer for 5-letter lock is MM400. The participant will open the lock to access the next task.

- Task 3: Hint–Computer [****]s, Olympic [****]s. Look the word in the bracket up in the dictionary. You should see a word that allows you to open the 4-letter lock.

The word in the bracket is **game.** The participant is expected to open the dictionary to look up the word to see a highlighted word, **play**, in the explanation of game. The participant will open the 4-letter lock to get the next question.

- Task 4: Five Effects of Prediction are: (1) the prediction effect, (2) the data effect, (3) the induction effect, (4) the ensemble effect, and (5) the () effect (hint: see p. 221 of a book). Use this word to unlock the tablet PC.

There is a book about prediction analytics, in which one chapter talks about the five effects of prediction. When opening the book, the participant will figure out that the fifth effect of prediction is *persuasion*. This word is the passcode for a table PC in the room. The next task comes up on the screen when opening the tablet.

- Task 5: [Picture of silver medal] This is a () medal. Find the publication year of a book that () wrote. Use this publication year to open the 4-digit lock.

The word in the bracket is silver and there is a book written by *Nate Silver*, in 2012, which is the 4-digit for the participant to get the key–The end!