Exploring Collaborative Navigation Support in Collaborative Product Search

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ABSTRACT

In the e-commerce domain, online retailers have begun exploring collaborative online shopping tools to provide a group of customers a close experience to the real-world, and consequently improve engagement in retail websites. In prior works, enabling and increasing a sense of *co-presence* has been shown to be an essential aspect in collaborative shopping as it can improve group coordination during the decision making process. One concrete manner to increase the sense of co-presence is *collaborative navigation*. Collaborative navigation is the process of allowing a group to navigate and share information via an intermediate interface. In our work, we investigate to what extent a group of collaborating users differ in their search and decision making behaviour when faced with either *separate* or *shared navigation* features (the latter being a specific type of collaborative navigation). To this end, we designed a collaborative shopping system that consists of a collaborative search system using a product catalogue as an underlying corpus. We conducted a user study with 30 groups of two to three participants that were given a collaborative shopping task using one of either separate or shared navigation. We find that shared navigation participants were more effective in their search space exploration, and navigation support did not significantly impact the purchase and post-purchase decision making stages. This is the first work to shed light on the impact of navigation support in collaborative search on the five stages of a group decision making process, with important design implications for collaborative shopping-oriented search systems.

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1 INTRODUCTION

In the e-commerce domain, online retailers have began exploring *collaborative online shopping* tools to provide a group of customers an experience closer to physical shopping in the real-world—and consequently improve engagement with the retail website. For instance, *Amazon*[1] offers its customers the ability to create collaborative wish lists and chat on its website; in addition, households can conduct voice search and shop together using the *Alexa* voice assistant. In addition, the COVID-19 pandemic has prompted a rapid change in how customers shop. *Squadded*[2] has launched the *"Shopping Party"* browser extension that allows users to shop virtually together with friends on fashion retailer websites. By enabling social engagement between collaborators on their website, retailers may observe business advantages such as increasing time on site, product views, and intention to return [14, 15].

Specifically in a collaborative shopping experience, a *group* of users will typically work through a series of *stages of group decision making* [11, 16]—ranging from the recognition of the collaborative shopping need, to the evaluation of shortlisted products [33] to deduce which one to ultimately purchase. A number of researchers have investigated how different collaborative features can support or hinder groups when working through a collaborative shopping task [5, 7, 37–39]. In particular, enabling and increasing a *sense of co-presence* has been shown to be an essential aspect in collaborative shopping as it can improve group coordination during the decision-making process [38]. One concrete manner to increase the sense of co-presence is through *collaborative navigation*.

Collaborative navigation is the process of allowing groups to navigate and share information via an intermediate interface [28]. Different types of collaborative navigation exist, such as *split screen* [38] and *shared navigation* [39]. Collaborative shopping systems often support users when navigating an e-commerce site by sharing a browser's session, which can make members in a group aware of the location of each other—or observe another member's shopping session [38]. Collaborative search systems have also been developed with navigation features in mind to improve the awareness of members, their coordination, and the sharing of knowledge [21].

Although collaborative search systems are not often connected to collaborative shopping systems in the literature, both kinds of systems provide similar functionality to aid in a collaborative scenario.[3] Specifically, navigation support features determine how a user employs a collaborative search system together with other users. For instance, in a *separate navigation features* setup (which we refer to as `SepNav`), users conduct their own searches and can act independently of other users. In contrast, in a *shared navigation features* setup (which we refer to as `SharedNav`), any action taken by a user such as submitting a query or clicking on a result may change the interface other members of the collaborating group currently see. While not common, shared navigation features have been shown to reduce conflicts between group members and make

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[1] https://www.amazon.com/hz/wishlist/intro — all URLs last accessed May 24th, 2021.
[2] https://www.squadded.co/
[3] Hereon in, we refer to both types of systems as *collaborative search systems.*

users more effective in their discussion [39]. However, previous works did not focus on understanding the differences in group behaviour of navigation support features that can influence the entire group decision making process [5, 37–39].

We investigate how the different stages of group decision making are impacted by the type of navigation support (SepNav vs. SharedNav) in a collaborative product search task. To this end, we designed a collaborative shopping system that consists of a collaborative search system, with a product catalogue as an underlying corpus. User interface features that users have come to expect from online shopping sites (such as faceted search) were included. Through a user study with $N = 64$ participants, we perform a comprehensive analysis of the effect of the navigational mechanisms during the group decision making process to answer the following research question (**RQ**): *How and when do navigational mechanisms impact the group decision making process in collaborative product search tasks?* We find that SharedNav participants were more effective in their search space exploration, and we find no significant impact of navigation mechanisms on the purchasing decisions and post-purchase decision evaluation stages of participants.

2 RELATED WORK

We provid an overview of close: collaborative navigation, collaborative shopping, and group decision making. Due to space limitations, we refer the reader to Morris [21] for a general introduction of collaborative search.

2.1 Collaborative Navigation

Collaborative navigation is a feature that determines how users navigate the functionalities of a collaborative system. Collaborative browsers are one type of system that can typically support synchronous collaboration via yoked views, where a user's interactions causes other the browsers of other group members to automatically execute the same interaction. For instance, recent technologies such as TogetherJS[4] provide web application developers with the ability to let users initiate a shared session on their website—alongside chat capabilities (through text or video/audio). Screen sharing solutions also support collaborative navigation. However, users involved can only share their screens—others have no ability to collaboratively control what is happening [32].

In the context of *collaborative search*, collaborative browsers and screen sharing solutions can support a group collaboratively searching. However, these browser solutions do not contain search-specific features. In contrast, CoSearch [1] was implemented to provide multi-device collaborative navigation to support *co-located*[5] collaborative search and giving each user a mobile device, centralised by a desktop computer. Similarly, WebSurface [34] and WeSearch [23] provide co-located users a common display that users can navigate in their collaborative search sessions.

The literature also provides examples of remote collaborative navigation to support collaborative search. SearchTogether is an example of a system where users can split their search results by opening them in a new browser tab, and sharing this with others. This is known as *separate* or *independent navigation*, where users in a collaborative group use available collaborative features independent of one another. This approach has been widely used by researchers in the area [25, 27, 29]. In contrast, *shared navigation* mimics collaborative browsing features, where users can see (in real-time) the interactions that other users make, such as mouse clicks, scrolls, or issued queries [5, 37–39]. However, *shared navigation* features may introduce competition in attention and resources, potentially distracting members from the interactions of others, and may *'fight'* for the control of the task or conversation [13]. This can have a negative effect on group coordination and require additional effort in conflict resolution [39]. To overcome this potential side effect of shared navigation, Yue et al. [38] introduced another form of collaborative navigation support called *split screen navigation*. Here, dyads can see the navigation of their partner in real time. Through a user study, the authors found that *shared navigation* best improves navigation in terms of alignments of what collaborators communicated, and what they were seeing (via an eye-tracker), but *split screen navigation* encourages more diverse searches (i.e., a better exploration of the search space). Our work builds on [38, 39]. Specifically, we extended SearchX, an open-source collaborative search system [27], to support *shared navigation* and to support a collaborative shopping experience. In contrast to [38, 39], we restrict *shared navigation* to the *Search Engine Results Page (SERP)*. We argue that this limited approach reduces the likelihood of user confusion, and will reduce the cognitive load of using the interface.

2.2 Collaborative Shopping

Morris [20] observed that 25.7% of the participants in their 2008 survey on collaborative web search had collaborative shopping needs. Although online shopping may not always involve search episodes, searching is an important part of the shopping journey, and facilitating a better search experience can impact customer experience [33]. A few works in collaborative shopping investigated the design and evaluation of collaborative features that can improve a collaborator's experience of co-presence and communication [15, 30, 37–39]. Co-presence support tries to increase collaborators awareness of each other in order to improve the social presence while shopping together. This has been achieved by developing system design components with collaborative navigation support [37–39] and embodiment [15]. Communication support or media richness has been studied as a component to support co-presence, but also to support coordination [30, 39].

Although many of the studies described above discussed how co-presence support can enhance collaborative shopping experiences, none have investigated how searching impacts the collaborative shopping experience. To bridge this gap, Gao et al. [7] developed ShopWithMe!, a collaborative shopping and searching system, and conducted a user study to investigate whether collaborative search tools can support collaborative shopping. They found that collaborative search improves information sharing among group members collaboratively shopping for experience goods. Our own work follows this line of inquiry. However, we aim to investigate *how collaborative navigation support can impact users in the group decision making process*, which also includes searching together as one of the stages in the process.

[4] https://togetherjs.com/

[5] One collaborative search system design dimension is *location* [9]: remote collaboration means that users are not co-located, and thus their coordination requires a means of communication such as text chat or video/voice chat. In contrast, co-located collaboration means that users are physically in the same space.

Figure 1: The SearchX interface, complete with novel components developed for this study. Refer to §3.1 for a description of each of the components highlighted by one of the fourteen numbers. Note that the chat interface is a popup—users can hide the popup to reveal all of the obscured interface components.

2.3 Group Decision Making

In the e-commerce environment, decision making has been extensively studied—focusing on how decision aids can improve the decision making process of customers [11]. Kim and Srivastava [16] described in general the customer's decision making process in e-commerce, and examined how social influence affects each decision making process stages. They argued that during a shopping episode, a customer typically goes over *five stages of the purchasing decision making process*. **Stage 1**: recognise their information need (e.g., defining product requirements such as price, colour, size). **Stage 2**: conduct exploratory searches of the product catalogue and collect the candidate products. **Stage 3**. evaluate and compare the candidate products. **Stage 4**: make a purchase decision. **Stage 5**: evaluate their post-purchase decision.

In addition, communication has been found to play a key role in group decision making. Nakamura et al. [24] also investigated group decision making in collaborative search in a restaurant booking task. Based on the conducted user study with 24 participants, they found that communication happens during the entire decision making task—with a leaning to more communication at the beginning and the end of the task. Given that very few works in collaborative search research studied the impact of collaborative search tools on decision making [12], we want to understand what impact collaborative search features such as navigation support have on group decision making in collaborative shopping.

3 COLLABORATIVE SEARCH SYSTEM

Recall that for our purposes, we consider a collaborative shopping system to be a collaborative search system with a product catalogue as corpus and user interface features specific for product search.

As a base for our collaborative search system, we chose to use an existing, modular, open-source collaborative search framework, SearchX [26]. One advantage of SearchX is that full collaborative functionality is available *without* the need for additional browser extensions. Indeed, SearchX was extended with a shopping vertical user interface, search filters, and shared navigation. In the remainder of this section, we provide an overview of our user interface, the corpus and retrieval settings we employ in our user study.

3.1 Search Interface

An annotated screenshot of our developed interface is shown in Figure 1. The main interface components are the following (numbers match up to the corresponding number superimposed on Figure 1):

1. The standard *query box* allows users to enter queries.
2. Users can select from different *facets* or categories of items pertaining to results presented to them.
3. The *task outline* button is provided for users to show the task whenever they wish to view it.
4. Anonymised *user icons* are shown at the top to provide users with a sense of awareness of their collaborating partner.
5. A *countdown timer* is present at the top-right of the interface, counting down to `0:00`. The countdown clock is synchronised across each user's system.
6. *Product search results* are presented on the SERP as 12 cards (three per row); complete with the main product image, product title, average rating, number of reviews, and product price. Pagination is also present, with links provided at the bottom of the results (not shown in Figure 1; results have been cropped to save space).
7. When the user clicks on a product link (via 6, 11, or 12), the product viewer is shown (inset in Figure 1 as a callout). Available information in

the product viewer includes the product title, description, image, price, average rating, and top 5 reviews. Individual reviews contained a title, rating, and message.

8 For each result, users can *save* the item by clicking the ♥ icon. If users wish to take an item forward, they can click the 🛒 icon.

9 *Search filters* are present, which provides users with the ability to filter by department, average customer rating, brand, and price. Once someone clicks in one of the filters, the server returns filtered search results. A reset button is implemented to remove all currently enabled filters for the issued query.

10 Users can view *recent queries*. Here, a list of all queries issued during the search session are displayed. Queries appear in reverse chronological order, with the most recently issued query appearing at the top, alongside the user icon of the user issuing it. A click on a recent query issues it in the query box 1.

11 The *saved items* component lists each of the items that were saved by the users; see 7.

12 The *shopping basket* component lists the items that users have decided to take forward; see 7.

13 *Chat functionality* is provided to allow users to communicate with one another during the collaborative search task. The chat component is a popup; users can hide chat functionality to reveal obscured components/results underneath.

14 When another user issues a new query, changes facet or filters results, this yellow popup box will appear to warn the user. After three seconds, the interface will be updated to reflect the new set of (filtered) results.

3.2 Shared vs. Separate Navigation

In order to answer our research question, we implemented two navigation support variations, *separate navigation* (`SepNav`) and *shared navigation* (`SharedNav`).

The `SepNav` condition is the baseline condition: participants of a collaborating group each issue their own queries, and view only their own search results on the SERP. This means that participants subjected to this condition did not see the popup 14 in Figure 1.

In contrast, in the `SharedNav` condition, participants within the group had their SERPs synchronised once one of three actions occurred: *(i)* any member of the group issued a query; *(ii)* filtered the search results; or *(iii)* changed the results page (via the pagination component). Our approach was inspired by Zhu et al. [39] and Yue et al. [38]. Our study however does differ in relation to SERP synchronisation, and would only occur if one of the three actions listed above occurred. Other interactions with the user interface, such as scrolling, were not synchronised. Thus, our participants still had the freedom to explore a limited set of search results independently. We chose this setup to limit user confusion [39].

The `SepNav` condition has been trialled not only as a baseline in collaborative shopping research [5, 7, 24, 39], but also in numerous studies in collaborative travelling planing, collaborative-work tasks, and collaborative search as learning [4, 18, 19, 22, 24, 25].

3.3 Data Collection, Indexing and Retrieval

We utilised the *Amazon* public dataset [17] which has also been widely employed in previous product search research [2, 10, 33, 35, 36, 40]. We selected six different product domains (Amazon departments) for our study as listed in Table 1. We chose these categories in order to provide a diverse product catalogue. In addition, these categories are common in the product search literature [2, 10, 35, 36, 40]. We filtered out any product without a title, description, price, or image, as these are essential for the user search interface. In total, 1,346,033 products were indexed; 851,462 products were skipped. In addition to the aforementioned product information, we also extracted the product's department, reviews, average rating (and thus could show the top five reviews in the product viewer, as shown at 7 in Figure 1). Each review consists of a rating, the review text, and the number of votes cast for the review being *helpful*.

Table 1: Data Collection statistics including the filtered products considered in this work.

Product Department	Used in this work	Provided in [17]
Electronics	364,099	498,196
Home and Kitchen	288,880	436,988
Beauty	176,670	259,204
Office Products	122,406	134,838
Sports and Outdoors	244,366	532,197
Toys and Games	230,858	336,072
All departments	**1,346,033**	**2,197,495**

We created an index of our data using `Elasticsearch` as our search backend. We indexed product title, description, reviews, departments, and brand as text field. Each text field was tokenised using a character n-gram tokeniser ($n_{min} = 2$ and $n_{max} = 10$). Results were returned using BM25 with default parameters. We employed multi-field retrieval on all text fields where the field of the highest score is used as the score of the document. For more details, we point the reader to our source code.[6]

4 EXPERIMENTAL DESIGN

4.1 Experimental Conditions

As outlined in §2, a number of experimental conditions have been trialled in previous works regarding navigational support in collaborative (shopping) systems. Importantly, our work aims not to compare novel or reproduce navigation support approaches, *but to understand how and when navigation support approaches affect the group decision-making process*. We randomly assigned participants to one of two conditions.

`SepNav` In this condition whenever one participant in a group searches, the SERP is updated only for the participant that posed a query.

`SharedNav` In this condition, whenever one participant in a group searches, the SERP is synchronised among all participants of the group.

Participants under both conditions used the interface as outlined in §3; those assigned to `SepNav` however would not see the callout 14 in Figure 1; participants worked independently.

4.2 Training and Main Task

We designed our study tasks intending to make them complex and nuanced enough to require collaboration to accomplish the shopping task [3]. In particular, based on observations in the literature, a shopping task could result in individualised searching

[6] Source code is available at https://github.com/felipemoraes/searchx. For access to the data, please e-mail the first author.

Alex and Charlie, a young couple who are your friends, just moved in together, and they have invited your and your group members to a housewarming party. Your group members have decided to buy a gift together for your friends. Together, you should decide on a budget in the range of $50,00 and $200,00.

You don't know yet what to buy, but you should make sure that you choose a gift that both Alex and Charlie will enjoy. You are not sure whether to give them an electronic product since Alex is a gadget nerd or to help one of them improve their home workspace since Charlie complained to your group recently about their sub-optimal working-from-home setup. Perhaps, Alex would like some sports accessories given their passion for outdoor sports.

Together with your group members, decide what to buy to bring with you to the housewarming party. Using our search system, find one product you think your friends will like. To do so, first your group should explore a number of different products and save the ones you find good candidates to give as a gift in the **Saved Items** widget.

After you have found a few candidates, discuss which one to settle on as the final gift to buy. One person of the group should put the final item your group decided to buy from the **Saved Items** widget to the **Shopping Basket** widget. You want to buy a good gift but are also pressed for time as the party will start in an hour. You have thus 30 minutes to find a gift for your friends.

Figure 2: The task information template, as presented to participants of the study. This is for the main study task only.

behaviour rather than collaboration and collaborative sense making [31]. Hence, with collaboration as a focal point, participants completed one training task, and one main task.

Training Task In this task, participants had 15 minutes to search for an everyday product that their employer will buy for each of them (the *same* product) to enhance working from home productivity. This task aims to familiarise participants with the collaborative search system, and to search together. The participants went over the first four stages of the group decision task outlined by Kim and Srivastava [16]. We did not require them to fill in a post-purchase decision questionnaire.

Main Study Task Figure 2 presents the template we used for the main task. The goal of this task is to elicit a collaborative shopping task so that we can observe the five stages of the group decision making process.

4.3 Experimental Procedure

We scheduled an appointment for an online lab experiment[7] with each group of participants at a time they were online together—preferably in different locations.[8] Once participants had accepted a consent form, they were redirected to our server with the instance of SearchX running for their assigned condition. An overview of the experimental procedure is shown in Figure 3. We now outline each of the steps.

1. The participants met up in a video call with the experimenter dispensing initial instructions. Participants were provided with a link to the experiment, after which the video call ended.
2. The experiment began with participants independently answering pre-task questions.
3. Next, participants were moved to an online *waiting room*, where they waited for other participants that signed up with them to finish the pre-task questions.
4. Once the participants moved to the collaborative search phase, they first undertook a short, automated, interactive guide of the SearchX interface. The interface's key features were highlighted to the participants, along with a short explanation of what the highlighted components do. Participants were then given the training task in order to familiarise themselves with the collaborative system. After 15 minutes, we automatically moved the participants to the main task.
5. Participants read the instructions for the main task, before undertaking it with their team member(s). Our participants had 30 minutes to complete the task that is outlined in Figure 2.
6. Once the main task was completed, we then provided a final, post-task questionnaire. This was completed individually.

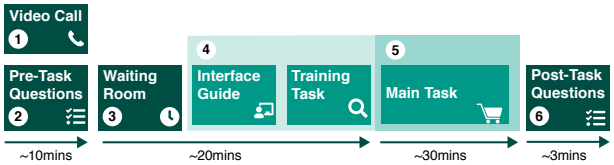

Figure 3: The experiment workflow for participants of this study. For more detail on the six main steps (as numbered on the diagram), refer to §4.3.

4.4 Pre-Task and Post-Task Questionnaires

Besides six demographic questions, our pre-task questionnaire included six collaborative search questions as presented by Morris [21] to aid priming of the participants for the upcoming collaborative search tasks. We included a short explanation of collaborative search and when and how it can happen, along with three images of groups collaborating (co-located and remote collaboration).

We provided a post-task questionnaire with 15 questions to capture each participant's *experiences* of shopping collaboratively with the provided system. Participants were able to indicate their perceived satisfaction with the group purchase decision, their opinions on the search and discussion phases that took place, their participation in the group decision, and their perceived difficulty of the group decision-making process. Answers were provided using a seven point Likert-scale; an open-ended question was also asked soliciting for their thoughts on the experience.

4.5 Study Participants

Over the course of 21 days, a total of 64 study participants completed our experiment successfully across the two experimental conditions. We recruited our participants from the *Delft University of Technology*, the Netherlands, via social media and internal communication channels. In total, 30 groups signed up in groups of two (26 groups) and three (four groups). We randomly allocated 13 groups of size two and 2 groups of size three to each experimental condition. Group members knew each other before the experiment. Their median age was 23 (min = 14 and max = 49). 32 of our participants identified as female, 30 as male, and two as non-binary. Our participants come from various nationalities: mainly India (17) and the Netherlands (16); the remaining participants are from EU countries (15), Mexico (3), Brazil (2), USA (2), Turkey (2), Nepal (2), Pakistan (2), China (2), and Indonesia (1). Most of our participants reported to be advanced English speakers. Their academic backgrounds varied: 31 reported possessing an undergraduate degree diploma as their highest academic degree; 22 a graduate degree; and and the remaining a high school diploma. We paid each participant a gift card valued at €12. The median time they spent in

[7] Due to COVID-19 regulations, we could not conduct a physical lab experiment.
[8] In case participants lived together and were in the same room, we asked them to not talk to each other during the experiment.

Table 2: Event types that were triggered by participants. Numbers refer to the system interface (see Figure 1).

Type	Events
Search	Issuing a query (via query box 1 or recent query 10), paginate SERP 6, change facet 2, filter SERP 9, click on search results 6, save or add to item to the shopping basket 8
Review	Click on or delete saved item 11
Chat	Send a chat message 13
Purchase	Click on or delete shopping basket item 12

our experiment was 60 minutes including pre-questionnaire (10 minutes) and post-questionnaire 3 minutes and 7 seconds.

4.6 Evaluation Measures

To evaluate the impact of collaborative navigation support in the group decision making process, we captured a variety of events triggered by participants as they performed the product search tasks. Table 2 shows the events aggregated by event type. In our data analysis we aggregated the events in four types to capture the first four stages of the group decision making process. More precisely, Search events were used to serve as a proxy for **Stage 1** (information need recognition) and **Stage 2** (information search). Review events allow us analyse **Stage 3** (evaluation of selected products) and Purchase events **Stage 4** (purchase decision). We also analyse how communication takes place during the decision process with Chat events.

Based on the interactions we captured with events described in Table 2, we employed on a range of evaluation measures commonly employed in *Interactive Information Retrieval* and collaborative shopping research [8, 18, 22, 38, 39].

We report aggregate search and review behaviours over a group 👥 and individually 👤. We report a number of behaviours associated with querying and interactions with the SERP such as product clicks, and time viewing products, for example. We also analysed the chat messages exchanged between participants; we report, among others, the time between messages and the balance of messages amongst group members. The latter was measured via the *Gini coefficient* [6] with the number of messages of each group member as input.

5 EXPERIMENTAL RESULTS

We now address the results in light of our overarching **RQ**. Significance testing between conditions was performed with the *Mann-Whitney U pairwise test* (at $\alpha = 0.05$), as we observed high variances for our measures. Note that ± values in the tables and corresponding narrative both indicate the *standard deviation.*

5.1 Descriptive Behaviour Analyses

Our **RQ** considers *how and when navigational mechanisms impact the group decision making process in collaborative product search tasks.* We first focus on the *how* part of our **RQ**. Table 3 presents an overview of our behavioural measures grouped by the four behaviour types: search, review, chat, and purchase. Results are reported across the two experimental conditions. For the first two columns of Table 3, mean values are the *average over the group* 👥 across each condition, and the last two columns *the average over participants* 👤 *across each condition.* We first examine the effects of collaborative navigation on the **Stage 1** (information need recognition) and **Stage 2** (product search and selection).

Example 1 - SepNav

monitor → gadgets → outdoor sports → gadgets → backpack → hiking backpack → power-bank → poles → desk → hiking backpack → traveling backback → survival backback → traveling backback → survival backback → hiking backpack → duo backpack → twin back-pack → hiking → hiking → hiking shoes → microphone → noise canceling headphones → noise canceling headphones wireless

Example 2 - SepNav

smart speaker → smart speaker → smart home → speaker → outdoor → outdoor → swing → sports→ projector → drone → bag → backpack → smart device → sports → remote working → projector → sports → camera → action camera → gopro → drone → instax → instax → gopro

Example 3 - SharedNav

ergonomic table → sports → adjustable table → adjustable desk → sports gear → sports gear → sport table → running table → running → table → running → ergonomic table → mood lamp → table running → home table → home office → indoor gym → portable gym → mixer → kitchen → blem-der mixer → blender mixer → art → boardgames

Example 4 - SharedNav

cool gadgets → electronic gadgets → bluetooth speaker → home office → bluetooth speaker → home office → working-from-home → home theater → sports → sports accessories → camping accessories → camping tent

Figure 4: Query logs over four individual search sessions, as captured in our experiment (with group sizes of two). Each colour represents a different participant. Underlined phrases are possible alternation of roles during the task.

Our analyses show that for the **Stage 1** (captured with behaviour measures **SE1–4**), we observe a significant difference in the number of queries issued via the search box (**SE1**) (10.44 ± 4.77 queries and 8.12 ± 4.79 queries for SepNav and SharedNav, respectively), and also via the recently issued queries component (**SE4**) (1.03 ± 1.89 queries and 0.22 ± 0.55 queries for SepNav and SharedNav, respectively) across *individual participants in each condition.* Additionally, we observe a significant difference in terms of the number of queries issued amongst group members measured as the Gini coefficient of the number of queries of each participant (**SE2** in Table 3). This finding shows that often a group member in the SharedNav condition issued more queries than the others. This suggests that collaborative navigation instantiated with SharedNav features affected the capability of participants to formulate a larger set of queries, with one member taking the role of issuing the queries for the other.

Turning our attention to **Stage 2** (captured with behavioural measures **SE5–10**), we observe that the number of unique products retrieved (row **SE9** in Table 3) shows significant differences between the two conditions—both when examining results on a per group and individual basis. Groups in SharedNav navigation collaboratively covered a smaller range of the search space as participants are always brought back together. However, groups in SepNav *individually* covered a smaller range of the search space, as each participant retrieved a different number of products. This finding suggests that group members subjected to SepNav retrieved more previously observed results (from queries earlier in the session) than group members in SharedNav. To highlight this further, we showcase in Figure 4 the query logs from four of our sessions, two each from SepNav and SharedNav. We can see in Example 1 that there was an overlap of the search space by members of a group subjected to SepNav (i.e., `hiking backpack` is first explored by one member, and later the other member issues the same query, while the former continued in a different direction). Our finding is different to Yue et al. [38]—the authors *could not* find a significant difference in the number of retrieved items over a hotel search task

Table 3: Mean (± standard deviations) of search, review, chat, purchase behavior metrics across all groups (👥) and participants (👤) in each condition. A dagger (†) next to SharedNav values denotes significance from the baseline, SepNav.

	Event Type and Measure		Over Groups		Over Participants	
			👥 SepNav	👥 SharedNav	👤 SepNav	👤 SharedNav
Search	SE1	Number of queries issued	22.27(±10.96)	17.33(±7.59)	10.44(±4.77)	8.12(±4.79)†
	SE2	Difference in number of queries among group members	0.08(±0.06)	0.15(±0.10)†	–	–
	SE3	Average query length (in words)	1.88(±0.57)	1.77(±0.39)	1.88(±0.61)	1.74(±0.44)
	SE4	Number of recent queries clicks	2.20(±3.10)	0.47(±0.74)	1.03(±1.89)	0.22(±0.55)†
	SE5	Maximum search pagination depth	4.35(±2.28)	3.45(±0.92)	4.23(±4.56)	3.18(±1.03)
	SE6	Number of filter selections	15.93(±9.04)	13.40(±8.40)	7.47(±5.87)	6.28(±5.33)
	SE7	Number of product clicks	9.53(±6.47)	9.07(±6.53)	4.47(±4.95)	4.25(±3.77)
	SE8	Number of saved products	10.73(±4.76)	9.07(±5.20)	5.03(±2.44)	4.25(±2.74)
	SE9	Number of unique product retrieved	698.13(±362.95)	465.73(±160.79)†	346.94(±194.15)	438.56(±149.05)†
	SE10	Average product view time (seconds)	11.73(±3.82)	10.98(±5.23)	10.54(±7.93)	9.83(±10.36)
Rev.	R1	Number of saved items click	18.40(±15.00)	9.40(±4.53)†	8.62(±6.89)	4.41(±3.30)†
	R2	Average saved product view time (seconds)	8.90(±5.49)	8.32(±5.32)	10.54(±7.93)	9.83(±10.36)
	R3	Number of deleted saved products	3.80(±5.45)	3.20(±5.17)	1.78(±3.23)	1.50(±3.03)
Chat	C1	Number of messages	70.20(±35.91)	74.40(±29.27)	32.91(±16.06)	34.88(±13.60)
	C2	Time between messages	25.69(±13.62)	21.96(±9.27)	56.78(±32.14)	48.67(±21.99)
	C3	Number of chat words	392.00(±214.54)	466.67(±210.20)	183.75(±104.03)	218.75(±114.68)
	C4	Number of chat clicks	23.47(±16.11)	19.47(±19.27)	11.00(±13.05)	9.12(±11.52)
	C5	Balance of messages among group	0.08(±0.05)	0.08(±0.05)	–	–
Purch.	P1	Number of basket products	1.93(±2.63)	1.87(±1.25)	0.91(±1.51)	0.88(±0.91)
	P2	Number of basket clicks	1.73(±3.37)	0.53(±0.74)	0.81(±1.97)	0.25(±0.51)
	P3	Number of deleted basket products	0.27(±0.59)	0.53(±1.13)	0.12(±0.34)	0.25(±0.57)
	P4	Time taken to add the last product to basket (mm:ss)	22:03 (± 5:15)	23:18 (± 4:49)	–	–

between the SepNav and SharedNav conditions. This difference can be explained by the fact that for our study, only the SERP was synchronised for group members subjected to SharedNav—and not over actions such as scrolling, or viewing specifics about a product.

Next, we analyse the impact of collaborative navigation behaviours pertaining to how groups evaluated their selected products during **Stage 3**. This analysis is based on metrics **R1–3** in Table 3. We observe that group members in the SharedNav condition interacted with the saved items interface component (11 in Figure 1) significantly more often SepNav than SharedNav (18.40 ± 15.00 vs. 9.40 ± 4.53). A possible explanation for this phenomenon is that group members subjected to SepNav relied more on the saved items component to know which item the other member was searching for (and selecting) at the same point in time.

We now look at the behaviour metrics for **Stage 4**. Purchase behaviour metrics **P1–4** in Table 3 show that groups in both conditions purchased and analysed purchased products put in the shopping basket in a similar manner. From metric **P4**, we observe that groups finished adding products to the basket on average at times of 22:03±5:15 minutes and 23:18±4:49 minutes for the SepNav and SharedNav conditions respectively. As participants were given 30 minutes to perform the search task, agreeing on the shopping basket after 22 – 23 minutes on average indicates sufficient time was available for groups to make the decision without time pressure.

Lastly, from Table 3 (row **C1–5**), we analyse the phase of discussions that occurred within the chat messages. We observe no significant impact of collaborative navigation on the discussion in terms of summary metrics. Interestingly, despite having an unbalance in the number of queries among group members in the SharedNav condition, we did not observe an unbalancing of the number of messages exchanged (row **C5** in Table 3). One would expect that participants in SharedNav that issued queries less frequently during the task would communicate more to the participants issuing more queries. This suggests that there was possibly an alternation between roles during the collaborative shopping task—this can also be seen in the underlined phrases in examples 3 and 4 of Figure 4.

5.2 Time-based Behaviour Analysis

We now focus on the *when* part of our **RQ**. In §4.6, we described the group decision making stages in sequence. However, group members could go back and forth in these stages. We zoom in on how this dynamics occurred along with the task. To do so, we show in Figure 5 a series of Markov models, where the stages outlined in §4.6 are represented as states. We split each session into two halves to demonstrate what is likely to happen at the start of the session when compared to the end of the session.

From Figure 5, we can first observe that groups in the SepNav condition had more search events in the first half of the session (62.90% of the events) than in the second half (39.64% of the events). Consequently, SepNav participants communicated less in the first half (28.82% of the events) than in the second half (40.28% of the events). In contrast, participants in SepNav condition to communicate more uniformly along with the session. Also, once a search event occurs, participants in the SharedNav condition are more likely in the first half of the session to send a message to their collaborators (31.32%) than SepNav participants (17.60%). This suggests that participants in the SharedNav condition alternate more between communicating and **Stage 1** and **Stage 2** of the decision making process. This is an important implication for future research as we can identify key timestamps of the session to facilitate the shared navigation among collaborators via chat features.

In terms of review events, SharedNav groups are less likely to continue in **Stage 3** during the first half of the session than SepNav groups. This is expected as group members have to explore more the saved items in order to coordinate and communicate their findings. Surprisingly, during the entire session, less than 0.01% of

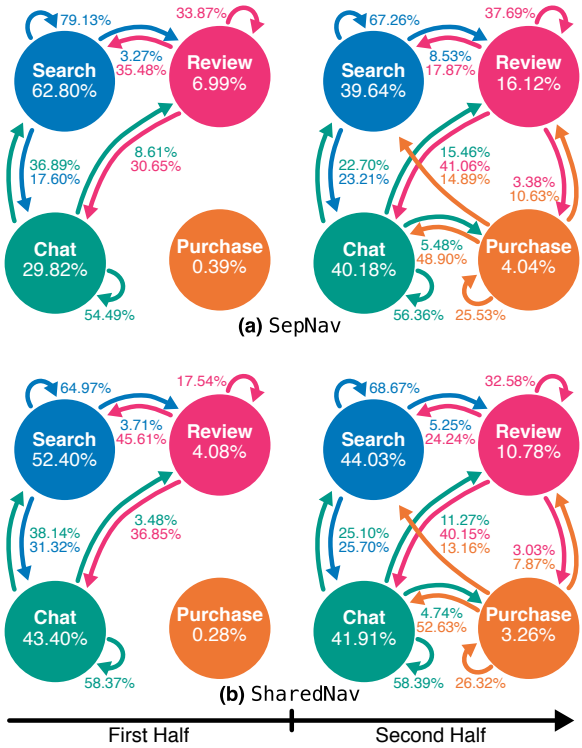

Figure 5: Markov model constructed based on the transitions between events described in Table 2.

transition events occurred between search and purchase events, suggesting that in both conditions, there is no direct transition to **Stage 4** from **Stage 1** and **Stage 2**. Additionally, we observe in both conditions that participants triggered search events after a purchase event (14.89% and 13.16%, for SepNav and SharedNav, respectively). Further analysis shows that this transition back to **Stage 1** and **Stage 2** from **Stage 4** is due to two reasons: *(i)* to only conduct more searches and confirm the purchase decision was final (7 groups and 6 groups in the SepNav and SharedNav condition, respectively); or *(ii)* to save and review more products and remake the purchase decision (3 groups and 5 groups in the SepNav and SharedNav condition, respectively).

5.3 Post-Purchase and System Perception

Finally, we present the perceived post-purchase satisfaction results in Table 4, or **Stage 5** of the decision-making process (row **PP1–5**). As we ran a simulated task, we are unable to capture how participants evaluate their purchase besides qualitative measurements. In this stage, we did not observe statistical differences for the perceived purchase decision satisfaction. This finding means that collaborative navigation did not impact the perceived satisfaction with the collaborative shopping task. On the other hand, in terms of system perception (row **SP1–6**), we observe that participants subjected to SharedNav found the search results less relevant than SepNav condition participants and that they perceived more technical issues with the system. This can be explained as the collaborative navigation is not something that participants were used to, even though we introduced the system and the features during the training task.

Table 4: Post-task questions regarding post-purchase satisfaction and system perception. Mean values (± standard deviations) are reported across conditions SepNav and SharedNav. A dagger (†) next to SharedNav values denotes significance from the baseline, SepNav.

	Measure		SepNav	SharedNav
Post-purchase	PP1	**Purchase decision satisfaction** (1 (not satisfied) - 7 (satisfied))	6.44(±1.16)	6.16(±1.44)
	PP2	**Search space exploration** (1 (not sufficient) - 7 (sufficient))	5.94(±1.27)	5.75(±1.41)
	PP3	**Discussed with others** (1 (not sufficient) - 7 (sufficient))	6.09(±1.28)	6.28(±1.08)
	PP4	**Expressed opinions** (1 (not sufficient) - 7 (sufficient))	6.19(±1.18)	6.38(±0.75)
	PP5.	**Own opinions impacted** (1 (disagree) - 7 (agree))	6.03(±1.23)	6.28(±1.11)
System Perception	SP1	**Relevance of search results** (1 (disagree) - 7 (agree))	5.62(±1.41)	5.06(±1.50)†
	SP2	**No system technical issues** (1 (disagree) - 7 (agree))	4.97(±1.99)	3.88(±1.93)†
	SP3	**Task difficulty** (1 (easy) - 7 (difficult))	3.34(±1.60)	2.97(±1.58)
	SP4	**Easiness of synchronisation** (1 (easy) - 7 (difficulty))	5.62(±1.41)	5.06(±1.50)
	SP5	**Awareness of each other** (1 (disagree) - 7 (agree))	5.47(±1.70)	5.16(±1.71)
	SP6	**Easiness of sharing knowledge** (1 (easy) - 7 (difficulty))	4.97(±1.99)	3.88(±1.93)

6 CONCLUSIONS

We investigated how the five stages of group decision (§2.3) making are impacted by the type of navigational support (separate vs. shared navigation) in a collaborative product search task. To this end, we conducted a user study with 64 participants. Participants were split between two systems: one that sought to have individuals search individually, with the other introducing shared navigation between group members. We observed that of the stages of group decision making, **Stages 1–3** were the most impacted by the navigation support. In particular, we found that participants of shared navigation were more effective in their search space exploration, and shared navigation caused less usage of other collaborative search features, such as viewing recent queries. We observed that shared navigation elicits participants to communicate more consistently during the task, and no significant differences were found across the metrics we considered for **Stage 4** and **Stage 5**.

Implications of this work demonstrate that considering online collaborative shopping tasks must be considered from the five-stage framework by [16], as it provides a more structured manner to understand the complex processes involved. We confirm that collaborative navigation does aid searchers when collaboratively shopping. We also confirm that the inclusion of chat tools also aids the process; not being co-located, chat provides an invaluable means of communication between group members. To the best of our knowledge, this study is the first that looks at user behaviour measures across independent and shared navigation systems in e-commerce. Although, our participants came from a young population (median age = 23), we argue that our insights can be useful as they open up a number of possible future research directions, such as: *(i)* identifying which types of products collaborative navigation may be particularly useful for; (ii) investigating collaborative shopping in smaller devices; and *(iii)* identifying other domains (such as academic search) where collaborative navigation may be suitable.

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