

Article

Optimizing On-Site Search Engines in E-Commerce: A Data-Driven Approach to UX Design, User Behavior and Performance Optimization

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Abstract

On-site search has become a critical component of e-commerce platforms, shaping product discovery, navigation, and purchasing decisions. While prior research has extensively examined search algorithms and information retrieval, less attention has been given to on-site search as a navigation environment in which interface design, visual guidance, and user search behavior jointly relate to search effectiveness and commercial outcomes. This study addresses this gap through three observational analyses using real-world behavioral data from a large Greek e-commerce retailer. Studies 1 and 2 employ before-and-after comparisons to examine changes associated with Search Results Page enrichment and the introduction of visual promotional guidance, while Study 3 descriptively examines generic query use and broad-to-narrow search behavior. The observed patterns show that Search Results Page enrichment coincided with lower refinement rates and improved commercial metrics, while visual guidance coincided with higher engagement and conversion-related outcomes. The behavioral analysis further indicates a strong prevalence of short, generic queries and patterns consistent with broad-to-narrow navigation. Overall, the findings suggest that on-site search performance is associated with both interface configuration and user search behavior. The study contributes real-world evidence on search as a navigation process and offers practical implications for retailers seeking to improve search-interface performance, while acknowledging the limits of observational before-and-after data for causal inference.

Keywords: on-site search; e-commerce; search results page; user behavior; search interface; visual guidance; search performance



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1. Introduction

E-commerce interfaces increasingly shape how consumers locate, compare, and evaluate products within large digital assortments, making information access and decision support central to online retailing [1,2]. Within this environment, on-site search can be understood as part of the retailer's digital navigation infrastructure because it connects consumers' information needs with product discovery and evaluation processes [1,3].

On-site search is particularly important when consumers face extensive product assortments and heterogeneous shopping goals, because online shoppers differ in the extent to which they arrive to buy, search, browse, or acquire information [3]. Interactive decision-support mechanisms can help consumers screen and compare alternatives more

efficiently, indicating that the design of search and navigation tools can shape how users progress through complex online choice environments [2]. Search should therefore be treated as a customer-journey touchpoint that supports both directed product finding and exploratory navigation [2,3].

Consumer choice in digital environments is often iterative rather than fully specified at the outset, because preferences can be constructed and revised as users encounter information and alternatives [4]. In e-commerce, this makes query reformulation, filtering, and progressive narrowing conceptually relevant to the decision process, particularly when users begin with broad goals and refine the available product space as they learn [2,3]. Accordingly, the effectiveness of on-site search depends not only on retrieval relevance but also on whether the interface supports users as they navigate and evaluate alternatives [2].

Contemporary retail interfaces are also being reshaped by artificial intelligence and increasingly adaptive customer-facing technologies [5]. Research on online customer experience further shows that digital design elements can influence cognitive, affective, social, and sensory responses, reinforcing the importance of evaluating interface design as part of the broader online shopping environment [6]. These developments increase the practical importance of understanding how search-interface configurations operate in real-world retail settings while maintaining a distinction between observable behavioral or commercial outcomes and subjective user-experience constructs.

This study addresses this gap by combining a focused literature review with an empirical analysis of real-world search behavior. Specifically, it examines how search-interface configurations and observable user search patterns are associated with behavioral and commercial performance indicators, including Click-Through Rate (CTR), Conversion Rate (CR), Average Order Value (AOV), refinement rate, and search-generated revenue. The analysis is based on anonymized search data collected over a nine-month period from a large e-commerce retailer in Greece.

The empirical investigation focuses on three complementary aspects of on-site search: changes associated with Search Results Page enrichment, changes associated with the introduction of visual guidance through promotional banners, and descriptive patterns in query formulation and broad-to-narrow search behavior. These analyses are interpreted as observational evidence rather than causal tests.

The contribution of this study is twofold. First, it provides real-world evidence on observable search behavior and interface-related performance patterns within an e-commerce context. Second, it connects research on consumer search, navigation, and interface design with operational search metrics, while maintaining a clear distinction between observed behavioral/commercial outcomes and broader subjective user-experience constructs that are not directly measured in the present dataset.

Accordingly, the scope of the present study is deliberately limited to observable search behavior and commercial search performance. Behavioral indicators such as click-through activity, refinement behavior, and search-session patterns are used to characterize how users interact with the on-site search environment, while conversion rate, average order value, and search-generated revenue capture commercial outcomes associated with those interactions. The study does not directly assess subjective user experience, perceived usability, user satisfaction, or accessibility; these constructs require complementary user-centered and accessibility-specific evaluation methods beyond the operational behavioral data available here. This distinction defines the empirical scope of the study and guides the interpretation of the findings throughout the manuscript.

2. Literature Review and Research Question Development

2.1. On-Site Search as a Customer Journey Touchpoint

On-site search has long been connected to the broader role of electronic marketplaces in reducing consumers' search costs and improving access to information about product offerings, prices, and sellers [1]. In digital retail environments, consumers are no longer restricted to the limited information available in physical stores, because interactive shopping environments allow them to locate, compare, and evaluate a wider range of product alternatives [7]. This makes search a foundational mechanism of online shopping, because it enables consumers to move from broad information access to more focused product evaluation [1,7]. From this perspective, on-site search should not be understood merely as a technical retrieval function, but as part of the consumer's decision journey within the e-commerce environment [2].

The importance of search becomes particularly evident in online stores with large assortments, where consumers must reduce complex sets of alternatives into manageable consideration sets [2]. Interactive decision aids, such as recommendation agents and comparison matrices, have been shown to improve the efficiency and quality of consumer decision-making by helping shoppers screen and compare alternatives more effectively [2]. This logic is directly relevant to on-site search, because search interfaces similarly help users translate an initial need or query into a narrower set of product options [2]. Search therefore acts as a bridge between consumer intent and product discovery, especially when users do not yet know the exact product they want to purchase [3].

Prior research also suggests that online shoppers enter retail websites with different goals, ranging from directed buying to active search, browsing, and knowledge-building [3]. This distinction is important because on-site search may serve different functions depending on the user's stage in the journey, from direct access to a known product to exploratory navigation across categories and alternatives [3]. For goal-directed users, search can shorten the path to a specific product by reducing the effort required to locate relevant results [1,3]. For exploratory users, search can support browsing, comparison, and preference formation by exposing users to relevant alternatives within a large assortment [3,7].

This broader view of search aligns with the idea that e-commerce performance depends not only on product availability, but also on how easily consumers can access, filter, and evaluate the available options [8]. In online retail platforms, consumer search costs and filtering mechanisms can influence consumer outcomes, seller outcomes, and platform-level performance [8]. This suggests that search design is commercially consequential, because the way alternatives are presented and filtered can affect how users interact with products and whether they progress toward purchase [8]. Search is therefore both an interaction and navigation mechanism and a commercially relevant component of the e-commerce environment; however, its commercial outcomes should not be treated as direct evidence of perceived usability or subjective user experience [9,10].

A "search as navigation" perspective is especially useful for e-commerce because consumers often use search not simply to retrieve a known item, but to structure the process of moving through a product space [3]. This perspective shifts attention from the search algorithm alone to the broader search environment, including the search results page, filters, sorting tools, visual cues, and other interface elements that guide user behavior [2,8]. The effectiveness of on-site search therefore depends on the interaction between system design and user behavior, rather than on technical relevance alone [2,7]. This study builds on this view by examining how search interface design and user search behavior jointly shape commercial outcomes in a real-world e-commerce environment [3,8].

Taken together, this literature supports a broader conceptualization of on-site search than a retrieval function alone. In this study, on-site search is defined as an interactive

e-commerce infrastructure through which users formulate information needs, navigate product assortments, refine alternatives, and progress toward commercial decisions. Its operation therefore spans information retrieval, navigation, and interface-mediated interaction, while the controls and content through which search is performed also create accessibility-relevant requirements concerning users' ability to perceive, understand, and operate the search environment. This definition provides the conceptual bridge between the commercial role of search and the human-centered interface principles considered in the following section.

2.2. Human-Centered Search Interfaces: Usability and Accessibility

The design of on-site search interfaces can be situated within the broader traditions of usability and human-centered design, which evaluate interactive systems in relation to users, goals, tasks, and contexts of use rather than commercial outcomes alone [11,12]. Empirical information-systems research similarly treats website usability as a multidimensional construct that includes navigability, content, interactivity, responsiveness, and user-oriented performance measures such as satisfaction and likelihood of return, rather than reducing usability to transaction outcomes [13].

This distinction is especially important in online retailing because customer experience encompasses multiple experiential dimensions that are shaped by interface design and can subsequently influence purchase behavior, rather than being equivalent to purchase behavior itself [6]. Accordingly, behavioral indicators such as clicks, refinement actions, and session duration can provide evidence about observable interaction patterns, while conversion rate, average order value, and revenue capture commercial performance; neither category, on its own, constitutes a direct measure of perceived usability or subjective user experience [6,13].

Accessibility constitutes a related but distinct quality requirement for interactive systems, focusing on whether people with diverse abilities can perceive, understand, and operate digital interfaces [14,15]. WCAG 2.2 formalizes web accessibility through the principles of perceivability, operability, understandability, and robustness, while EN 301 549 specifies functional accessibility requirements and corresponding evaluation procedures for ICT products and services in the European context [14,16]. Ability-based design research further emphasizes that interfaces should adapt to, and be evaluated against, the abilities of users rather than presuming a single normative user profile [15].

These principles are directly relevant to e-commerce search environments because filters, navigation structures, visual banners, and dynamically presented results are interface components through which users must locate information, make selections, and progress toward task goals [11,13]. The present study therefore treats usability, subjective user experience, and accessibility as broader human-centered quality dimensions that contextualize search-interface design, while limiting its empirical claims to the behavioral and commercial indicators available in the operational dataset. This distinction provides the conceptual boundary for the analyses that follow: the next sections examine how structural and visual characteristics of Search Results Pages are associated with observed navigation, engagement, and commercial outcomes, without inferring direct improvements in perceived usability, subjective user experience, or accessibility conformance.

Recent research further strengthens the need to evaluate contemporary digital interfaces through a human-centered lens. In a randomized controlled experiment conducted in an online shop context, Vollenwyder et al. found that higher conformance with web-accessibility standards did not by itself produce statistically significant improvements in measured usability or user experience, although qualitative responses indicated more differentiated benefits for participants with and without visual impairments [17]. This

evidence supports a central distinction in the present study: accessibility conformance, perceived usability, subjective user experience, and observable behavioral or commercial performance are related but non-equivalent dimensions and should not be inferred from one another. At the same time, artificial intelligence is becoming increasingly embedded in retail-facing technologies, with research in the *Journal of Retailing* emphasizing that the value and adoption of AI depend on the nature of the customer-facing application and the context in which it is deployed [5]. More recent meta-analytic evidence on AI-based virtual assistants similarly shows that customer, technology, and shopping-context characteristics jointly shape cognitive, emotional, and usage responses, reinforcing the importance of evaluating intelligent retail interfaces in relation to users and contexts rather than technological capability alone [18]. This human-centered perspective has also acquired direct regulatory relevance in European e-commerce. Directive (EU) 2019/882, commonly referred to as the European Accessibility Act, explicitly covers e-commerce services and has applied across the European Union since 28 June 2025, making accessibility a current design and compliance consideration for digital retail services operating in the European market [19–21].

A complementary interaction-level perspective is provided by ISO 9241-110:2020, which specifies general principles for interaction between users and interactive systems and provides a framework for applying them in interface design and evaluation [22]. For on-site search, this framework is relevant because search interaction depends not only on whether users can retrieve products, but also on whether the interface supports task-oriented, understandable, predictable, learnable, controllable, error-robust, and engaging interaction. These principles provide a normative basis for considering filters, tabs, refinement controls, search feedback, and other navigational elements as parts of the interaction architecture rather than solely as mechanisms for improving commercial performance. The present study does not conduct a formal ISO 9241-110 conformance evaluation; instead, the standard is used to strengthen the conceptual distinction between observed performance outcomes and the broader interaction qualities that a human-centered search interface should support.

Applied to on-site search, these frameworks imply that interface components should be evaluated against distinct interaction and accessibility requirements rather than treated as commercially neutral design features. Filters and refinement controls concern task suitability, controllability, predictability, feedback, and error robustness under ISO 9241-110, while their accessibility also depends on operable controls, understandable labels and instructions, and perceivable changes of state under WCAG 2.2 and related European ICT requirements [14,16,22]. Tabs and category structures similarly raise requirements concerning consistency, learnability, understandable navigation, keyboard operability, and the communication of selected states [14,16,22]. Visual banners may guide attention, but their human-centered use also requires that information is not dependent on visual presentation alone and that non-text content and contrast remain accessible [14,16]. Dynamically updated result areas and search feedback require predictable system responses and perceivable status changes so that users, including those relying on assistive technologies, can understand the consequences of queries and refinements [14,16,22]. The scholarly evidence complements these normative requirements in two ways. First, a systematic review of web-accessibility evaluation shows that accessibility engineering draws on standards-based assessment together with evaluation methods and user-centered procedures rather than treating conformance checking as a complete account of user experience [23]. Second, empirical research focused specifically on e-commerce websites has documented substantial WCAG-related barriers across commercial sites, with perceivability and contrast among the most prominent problems identified in automated evaluation [24]. Together with evi-

dence from an experimental online shop setting showing that standards conformance and measured usability or user experience should not be treated as interchangeable [17], these studies support evaluating accessibility as a distinct quality dimension of digital retail interfaces. In European e-commerce, these design considerations also have a regulatory dimension because the European Accessibility Act covers e-commerce services and reinforces the need for accessible digital information and interaction [19–21]. This mapping does not imply that the interfaces examined in the present study satisfy ISO 9241 or accessibility requirements; rather, it identifies human-centered qualities that would need to be assessed independently of the behavioral and commercial outcomes observed in the dataset.

A comprehensive empirical evaluation of these human-centered qualities would therefore require methods that complement platform analytics. Standardized questionnaires such as the System Usability Scale (SUS) can provide a global measure of perceived usability [25], while the User Experience Questionnaire (UEQ) is designed to quantify subjective evaluations of interactive products [26]. Task-based usability testing and think-aloud protocols can reveal where users encounter difficulties while formulating queries, interpreting results, or applying refinement controls; expert heuristic evaluation can identify interface-level violations of established usability principles; and eye-tracking can provide evidence about visual attention and search behavior that cannot be inferred from clicks or conversion metrics alone. Accessibility assessment likewise requires a combination of standards-based auditing and user-centered evaluation rather than reliance on commercial performance indicators [17,23]. Large-scale automated accessibility audits can identify technical barriers such as inadequate contrast and missing accessible names across digital interfaces [27], but such checks do not substitute for direct evaluation with users. These methods were not part of the present observational dataset and are identified here to clarify the methodological distinction between the behavioral and commercial outcomes analyzed in this study and a direct empirical evaluation of perceived usability, subjective user experience, or accessibility conformance.

Established interaction-design traditions provide complementary lenses for interpreting these human-centered principles. Heuristic evaluation conceptualizes usability problems through general interface principles and provides a structured means of identifying potential interaction difficulties without equating such inspection with observed commercial performance [28]. Shneiderman's interaction-design principles similarly emphasize consistency, informative feedback, error prevention and recovery, user control, and reduced memory burden, all of which are relevant to search interfaces in which users repeatedly formulate, inspect, and refine queries [29]. Within digital consumer research, the concept of flow has also been used to explain navigation in computer-mediated environments as an experiential state associated with focused involvement and interaction with the digital environment [30]. Scenario-based usability engineering offers a further user-centered perspective by organizing design and evaluation around concrete user activities and interaction scenarios rather than interface features in isolation [31]. These traditions are used here as conceptual reference points rather than as evaluation procedures applied in the empirical studies: the present research did not conduct heuristic inspection, scenario-based usability testing, or direct measurement of flow.

2.3. Search Interface Design and Search Effectiveness

Given that consumers frequently engage in iterative and exploratory search processes, the design of the search interface plays an important role in supporting how users navigate, evaluate, and refine available alternatives in digital environments [2,8]. While search algorithms determine which results are retrieved, the interface determines how information is structured, presented, and transformed into actionable choices for consumers [32,33].

Therefore, effective e-commerce search requires not only accurate information retrieval but also interface mechanisms that facilitate exploration, comparison, and decision-making throughout the customer journey [2,8].

Prior research in human–computer interaction and information systems suggests that users interact with digital environments through continuous cycles of information seeking, feedback evaluation, and decision adjustment [32,34]. Within e-commerce contexts, search result pages represent a central interaction point because they translate user queries into structured product alternatives that influence subsequent navigation and choice behavior [2,8]. As consumers often face extensive online assortments, interface elements that organize information can reduce cognitive effort and improve users' ability to identify relevant options [2,4].

Search result page enrichment, including structured navigation elements such as filters, categories, sorting options, and faceted navigation, enables users to progressively narrow large product spaces according to their preferences and decision criteria [8,35]. Refinement tools such as sorting and filtering are integral to sequential online search because they allow consumers to update the set of alternatives considered as the search process unfolds [35]. This functionality aligns with broad-to-narrow search behavior, where initial uncertainty is gradually reduced through interaction with the search environment [34,36].

From a decision-support perspective, search-interface features can support consumer decision processes by helping users evaluate alternatives and process information more efficiently [2]. Research on online retail platforms further shows that search and filtering mechanisms can influence consumer behavior by shaping how users discover, compare, and select products from large assortments [8]. Consequently, interface design choices are relevant to both interaction processes and commercial outcomes; however, their contribution to perceived usability or subjective user experience requires direct user-centered evaluation.

Despite extensive research on search algorithms and information retrieval technologies, less attention has been given to understanding how search result page design influences real-world consumer search behavior and business outcomes within commercial e-commerce environments [8]. Existing research highlights the importance of reducing search friction and supporting consumer decision-making, but empirical evidence connecting specific search interface improvements with behavioral and commercial metrics remains comparatively limited [9,10]. Addressing this gap, the present study examines whether enriching the search results page with additional navigation and organizational elements is associated with improvements in search effectiveness and commercial performance.

Taken together, prior research suggests that the organization of search results can shape how efficiently consumers navigate product assortments and how they progress toward commercially relevant outcomes [2,8]. However, evidence linking concrete Search Results Page redesigns to observed refinement behavior and commercial search performance under real-world operating conditions remains comparatively limited [9,10]. This motivates the first research question:

RQ1: *How is Search Results Page enrichment associated with users' search refinement behavior and commercial search performance?*

2.4. Visual Guidance Within Search Environments

Beyond structural interface elements such as filters and navigation tools, visual information plays an important role in shaping how consumers allocate attention, process information, and make decisions in digital environments [37,38]. As online consumers are exposed to increasingly complex information environments, visual cues can help direct attention toward relevant information and reduce the effort required to identify meaningful alternatives [37,39]. Within e-commerce environments, visual guidance mechanisms there-

fore serve not only aesthetic purposes but also functional roles by supporting information processing and product discovery [2,6].

Research on visual attention demonstrates that consumers do not process all available information equally but selectively allocate attention based on the salience and relevance of visual elements within an interface [37,38]. Visual characteristics such as images, placement, and presentation format influence how users navigate information spaces and determine which elements receive cognitive processing during decision-making [37,38]. This is particularly relevant in online retail environments, where consumers must evaluate numerous products and information cues within limited attention capacity [4,6].

In e-commerce contexts, visual elements can enhance the customer experience by increasing engagement and facilitating interactions between consumers and digital interfaces [6]. Effective digital interface design combines informational and visual elements to support consumers throughout their decision journey and improve the overall quality of online experiences [40]. Therefore, visual components embedded within search environments may function as navigational aids that help consumers discover relevant products and interpret available options more efficiently [2,8].

Promotional banners and other visual cues within search result pages represent one form of visual guidance because they introduce additional pathways through which consumers can interact with product information [6,38]. Rather than viewing banners only as advertising elements, they can be understood as interface components that influence attention allocation and guide users toward specific areas of the product assortment [6,37]. This perspective aligns with the broader view of search as navigation, where interface elements actively shape the user journey instead of passively displaying retrieved results [2,8].

Although prior research has extensively examined visual attention, online advertising, and digital customer experience, less empirical evidence exists on how visual guidance elements embedded directly within search result pages affect actual search behavior and commercial outcomes in real-world e-commerce settings [6,8]. Understanding this relationship is important because search environments increasingly combine retrieval mechanisms with visual and interactive components designed to support exploration and product discovery [8]. Building on this perspective, the present study examines whether the integration of visual guidance elements within search result pages is associated with changes in user engagement and search-related performance outcomes.

Accordingly, visual guidance within search environments may alter how users allocate attention and engage with product information, yet its role when embedded directly within real-world Search Results Pages remains insufficiently documented [6,37]. The second research question therefore examines the observed behavioral and commercial patterns associated with such visual guidance:

RQ2: *How is the integration of visual guidance within Search Results Pages associated with user engagement and commercial search performance?*

2.5. Understanding User Search Behavior in E-Commerce

While on-site search represents a critical touchpoint within the online customer journey, its effectiveness depends not only on the technical ability of a system to retrieve relevant products but also on how consumers formulate needs, explore alternatives, and interact with available information during the decision process [2,3]. Understanding user search behavior is therefore essential because online consumers frequently engage in dynamic and iterative processes in which their preferences evolve as they acquire additional product information [3,4].

Consumer decision-making research suggests that users often enter choice environments with incomplete or uncertain preferences rather than fully defined purchase inten-

tions [4]. As a result, online product search frequently becomes a process of preference construction, where consumers progressively learn about available alternatives, evaluate attributes, and refine their choices throughout the interaction with the digital environment [2,4]. This perspective suggests that search behavior should not be viewed only as the execution of a predefined information need, but also as an exploratory mechanism that helps consumers structure their decision process [3].

Prior research on online browsing behavior further demonstrates that consumers use websites with different underlying goals, ranging from highly directed purchase activities to exploratory information acquisition [3]. Users with clear purchase goals tend to follow more focused navigation paths, whereas exploratory users engage in broader search activities to discover information and evaluate possible alternatives [3,41]. Consequently, search behavior within e-commerce environments reflects varying levels of consumer uncertainty, knowledge, and decision readiness rather than a single uniform interaction pattern [3,41].

A central characteristic of online search behavior is that consumers rarely complete their decision process through a single interaction, but instead rely on iterative search and refinement activities as they navigate large information spaces [34,36]. Users frequently begin with broader information needs and progressively narrow their focus as they receive feedback from the system and develop a clearer understanding of available alternatives [34,36]. In e-commerce contexts, this behavior is reflected in broad-to-narrow search strategies, where users may initially submit generic queries and subsequently refine their searches through more specific terms, filters, or additional navigation actions [3,8].

Query reformulation and refinement are therefore not necessarily indicators of search failure but can represent natural components of an exploratory search process [36]. During online shopping journeys, consumers continuously adapt their search strategies based on the information presented to them, making search interaction a feedback-driven process between user intent and system response [2,36]. This highlights the importance of understanding search behavior not only through final outcomes such as purchases, but also through intermediate behavioral signals such as query refinement, navigation patterns, and engagement with search results [3,41].

This behavioral perspective has important implications for e-commerce search design because the effectiveness of search depends on how well the system supports users throughout this iterative decision journey [2,8]. If consumers rely on broad initial queries and progressively refine their needs, search interfaces must provide mechanisms that facilitate exploration, filtering, and movement from general intentions toward specific product choices [8]. Therefore, understanding user search behavior provides the foundation for examining how search interface characteristics, such as result page organization, filters, and navigation aids, can influence search effectiveness and commercial outcomes.

The literature therefore portrays e-commerce search as an iterative navigation process in which users may begin broadly and progressively narrow their information needs through reformulation, filters, and other navigation mechanisms [3,36]. Because the present data allow these patterns to be characterized descriptively rather than tested as a causal relationship, the third research question is formulated as follows:

RQ3: *What query formulation and refinement patterns characterize users' on-site search behavior in e-commerce?*

2.6. Literature Search and Evidence Selection

The literature review was developed through a targeted, narrative search intended to integrate foundational research with contemporary evidence relevant to on-site search, e-commerce interface design, user search behavior, usability, accessibility, and AI-enabled retail interfaces. Searches were conducted across major scholarly databases and publisher

platforms using combinations of terms including “on-site search,” “e-commerce search,” “search interface,” “search results page,” “query refinement,” “search behavior,” “website usability,” “web accessibility,” “human-centered design,” and “artificial intelligence” with “retail” or “e-commerce.” Priority was given to peer-reviewed journal articles directly addressing the constructs examined in the manuscript, with seminal studies retained where they provide foundational theoretical grounding and more recent studies used to reflect contemporary interface, accessibility, and AI-related developments. Institutional and standards-based sources were included where authoritative technical or regulatory guidance was required, particularly ISO 9241, WCAG 2.2, EN 301 549, and the European Accessibility Act. Sources that addressed search or digital technology without a clear connection to e-commerce interaction, interface design, user behavior, usability, or accessibility were not used to support the manuscript’s central theoretical claims. This procedure was designed to improve transparency regarding evidence selection while remaining consistent with the narrative, theory-building purpose of the review rather than representing a systematic review or meta-analysis.

3. Materials and Methods

3.1. Research Objectives

This study investigates how on-site search interface configurations and search behavior are associated with observable user interaction patterns and commercial search performance within a large e-commerce platform. More specifically, it examines how search interface design and user search behavior are associated with search-related behavioral indicators and business outcomes.

The empirical analysis focuses on user behavior during search interactions, associations between search-interface features and key performance indicators (KPIs), and observed changes following interface interventions.

Rather than testing causal effects under controlled experimental conditions, the study analyses naturally occurring changes in the search interface using observational data collected during normal business operations.

3.2. Research Design

The study adopts a quasi-experimental observational design based on before-and-after comparisons of search performance metrics. Unlike randomized controlled studies, users were not randomly assigned to different search interface versions, nor was a simultaneous control group available. Consequently, the analyses identify associations between interface changes and observed outcomes rather than causal relationships.

Three observational analyses were conducted, each examining a different aspect of on-site search:

Study 1 investigates whether enriching the Search Results Page (SRP) with additional navigation and visual elements is associated with changes in search effectiveness.

Study 2 examines the relationship between promotional banners and user engagement.

Study 3 describes users’ preference for generic search queries and broad-to-narrow search behavior.

Throughout the paper, findings are interpreted as observational evidence rather than proof of causality.

3.3. Data Source and Study Period

The empirical analysis is based on real-world data collected from the on-site search platform of a large-scale Greek e-commerce retailer. The available dataset covers the period from 2 September 2024, to 31 May 2025, providing a sufficiently broad temporal scope

to capture normal variations in user behavior while minimizing the influence of isolated promotional events or short-term fluctuations.

All data were fully anonymized prior to analysis to ensure compliance with the General Data Protection Regulation (GDPR). The retailer's on-site search platform records a wide range of behavioral and commercial performance indicators, including:

For operational clarity, the measures used in this study are treated as indicators of two empirically observable domains. Search-related measures such as click-through activity, query refinement, session duration, and query formulation are interpreted as behavioral indicators of how users interact with the on-site search environment, whereas conversion rate, average order value, and search-generated revenue are treated as indicators of commercial search performance. These measures are not operationalized as direct measures of perceived usability, satisfaction, subjective user experience, or accessibility. Consequently, the analyses assess changes and associations in observable search behavior and commercial performance and do not constitute a standardized usability evaluation or an accessibility conformance assessment.

- Search queries
- User sessions
- Product clicks
- Click-Through Rate (CTR)
- Conversion Rate (CR)
- Average Order Value (AOV)
- Session Duration
- Refinement Rate
- Revenue attributed to search interactions

3.4. Sampling Strategy

Although the retailer's search platform continuously records all search activity, the present study does not analyze the complete search log. Instead, a purposive sampling strategy was adopted, whereby each study focuses on a representative high-frequency search query selected according to its search volume and relevance to the search functionality under investigation. This approach enables a focused examination of performance patterns associated with selected search configurations under real-world operating conditions.

For each selected query, aggregated behavioral and commercial performance metrics were extracted directly from the retailer's search platform and compared across two consecutive observation periods. Rather than analyzing individual user-level interactions, the study evaluates changes in aggregated search performance before and after the implementation of specific search interventions. This methodology enables a focused assessment of individual search functionalities while reducing the influence of unrelated search behavior occurring across the broader product catalogue.

Specifically, the query "Samsung" was selected for Study 1, and the query "iPhone" was selected for Study 2. These queries were chosen because of their consistently high search volumes and commercial importance. Study 3 was conducted using aggregated search-log data covering the entire study period.

Because only selected high-volume queries were examined in Studies 1 and 2, the findings should not be interpreted as representative of all search queries or product categories within the platform.

3.5. Data Processing

Behavioral metrics were extracted directly from the retailer's search analytics platform. The platform aggregates user interactions at the query level, allowing comparison of

search performance across predefined observation periods. The following preprocessing procedures were applied before analysis:

- Duplicate records were removed;
- Bot-generated traffic was excluded using the retailer's internal traffic filtering mechanisms;
- Behavioral metrics were aggregated at the query level;
- Sessions were defined according to the retailer's analytics platform configuration;
- Purchases were attributed to search using the retailer's existing attribution model.

Because the study relies on aggregated operational data, individual-level behavioral trajectories could not be reconstructed.

Key variables analyzed include the number of searches per session, revenue generated through search, the proportion of queries leading to conversions, and the contribution of search to total revenue.

The operational dataset available for the present analyses is aggregated at the query and observation-period level. Duplicate records were removed, and bot-generated traffic was excluded through the retailer's existing internal traffic-filtering mechanisms; however, the study did not independently validate or benchmark the platform's bot-detection procedure. Sessions follow the retailer's analytics-platform configuration, and purchases are linked to search through the retailer's existing attribution model. Because the extracted dataset does not preserve individual-level identifiers or complete user-level trajectories, repeated sessions by the same user cannot be identified or modelled separately. Likewise, the available analytical extract does not permit systematic segmentation by user characteristics or traffic-acquisition source. Although some platform reporting may contain device-related information, device distribution and mobile-versus-desktop differences were not consistently available at the level required across the three analyses and are therefore not treated as controlled explanatory variables in this study. These data-availability constraints limit the ability to determine whether the observed aggregate patterns differ across devices, traffic sources, user segments, or repeat-visit behavior.

3.6. Analytical Approach

The study primarily employs descriptive and comparative observational analyses. Descriptive statistics were used to summarize search behavior, including query frequencies, refinement behavior, search sessions, and commercial performance indicators.

For Studies 1 and 2, aggregated metrics were compared between consecutive observation periods before and after interface modifications. Because the studies do not include randomized assignments or concurrent control groups, comparisons should be interpreted as observational associations.

The datasets used in this study are presented through structured tables aggregated on a weekly and monthly basis. These tables include key performance indicators such as sessions, queries, click-through rate (CTR), conversion rate, and revenue metrics.

3.7. Observational Analyses

To provide a synoptic view of the empirical design, Table 1 summarizes the three observational studies, their principal focus, analytical logic, outcomes, and interpretive scope.

Studies 1 and 2 involve multi-component interventions implemented in a live commercial environment. The available before-and-after data therefore capture the overall pattern associated with each intervention package rather than the independent contribution of every simultaneously introduced component. In Study 1, filters, tabs, and visual/navigation elements form part of the broader SRP redesign; in Study 2, the analysis concerns the visual/promotional intervention as implemented. Accordingly, the manuscript does not

attribute the observed changes separately to individual components where their effects cannot be empirically disentangled. Study 3 is analytically distinct because it describes naturally occurring search behavior rather than evaluating an interface intervention.

Table 1. Overview of the three observational studies and their analytical scope.

Study	RQ	Query/ Use Case	Intervention	Period	Sample	Metrics	Analysis	Main Finding	Main Limitation
Study 1	RQ1	Samsung	SRP redesign: tabs, banners, enhanced filters	Sep–Oct 2024	6435 searches	Refinement; CR; AOV; search revenue	Before–after observational comparison	Refinement 50→25%; CR 0.89→1.10%; AOV €310→€330; revenue €8680→€11,550	Multi-component change; no control/randomization; components not isolated
Study 2	RQ2	iPhone	Promotional banner/visual guidance	Apr–May 2025	10,264 before; 9965 after	CTR; banner clicks; engagement; duration; CR; AOV	Before–after observational comparison	Engagement 3489→4476; duration 1:42→2:27; CR 2.3→2.7%; AOV €365→€387	Seasonality/novelty/concurrent factors; banner effect not isolated
Study 3	RQ3	Naturally occurring queries	No intervention	2 Sep 2024–31 May 2025	Full dataset; total not reported	Query type/length; generic prevalence; refinement/navigation	Descriptive aggregate analysis	~76% single-word/generic; broad-to-narrow navigation pattern	Aggregated data; no user trajectories; limited segmentation

3.7.1. Study 1: Search Results Page Enrichment

Study 1 examines whether a comprehensive Search Results Page redesign is associated with changes in search behavior and commercial performance. The redesign combined improved filters, category tabs, and visual banners; therefore, the analysis evaluates the combined interface modification rather than the independent contribution of each component.

Because these changes were implemented together, the analysis evaluates the outcomes associated with the combined interface redesign rather than the contribution of any individual component. Performance before and after implementation was compared using refinement rate, conversion rate, average order value, and search-generated revenue.

Accordingly, Study 1 addresses RQ1 by comparing refinement rate, conversion rate, average order value, and search-generated revenue before and after the Search Results Page redesign.

The study adopts a before-and-after comparative design based on two consecutive monthly periods. The high-frequency query “Samsung” was selected as the unit of analysis due to its consistently high search volume, allowing meaningful comparisons before and after the Search Results Page redesign. Behavioral and performance data were extracted directly from the retailer’s on-site search platform, which records search interactions, user engagement metrics, and commercial performance indicators. For each period, all search sessions associated with the selected query were aggregated and analyzed, enabling the evaluation of the redesign under real-world operating conditions.

The observational comparison consists of two phases:

Phase 1: Baseline measurement of search performance for a high-frequency query (“Samsung”) under a minimal interface configuration.

Phase 2: Evaluation after redesign, including the introduction of visual elements, structured navigation (tabs), and enhanced filtering options.

Performance is assessed by comparing key metrics across the two phases, including refinement rate, conversion rate, and revenue contribution.

3.7.2. Study 2: Visual Guidance and Promotional Banners

Study 2 investigates whether introducing promotional banners into the Search Results Page is associated with changes in user engagement and commercial performance. It addresses RQ2 using Click-Through Rate (CTR), session duration, conversion rate, and revenue-related indicators available from the retailer's search platform.

Although comparisons were made using consecutive monthly periods, the study acknowledges that seasonal variation, marketing campaigns, pricing changes, inventory availability, and traffic composition may also influence observed outcomes. Accordingly, findings are interpreted as associations rather than causal effects. In addition, increased interaction immediately following banner introduction may partly reflect a novelty effect, whereby users initially engage with new interface elements before behavior stabilizes over time.

The study follows a before-and-after comparative design based on two consecutive monthly periods. The high-frequency query "iPhone" was selected as the unit of analysis due to its consistently high search volume and commercial relevance, enabling a meaningful comparison before and after the introduction of visual content. Aggregated search performance metrics were extracted directly from the retailer's on-site search platform, providing behavioral and commercial indicators associated with the selected query under real-world operating conditions.

The observational comparison compares two distinct periods. During the first period, Search Results Pages (SRPs) were presented without any supporting visual content. In the second period, the same pages were enhanced with promotional banners, trend-based recommendations, and visually organized product categories. By monitoring users' interactions with these visual elements, the study evaluates their contribution to overall search effectiveness and commercial performance within the e-commerce environment.

3.7.3. Study 3: Generic Queries and Broad-to-Narrow Search Behavior

Study 3 addresses RQ3 by describing users' query formulation and broad-to-narrow navigation patterns. Particular attention is given to the proportion of short or generic queries, query reformulation behavior, and reliance on navigation tools such as filters and category tabs. The analysis is descriptive and aims to characterize behavioral patterns rather than establish causal relationships.

More specifically, the analysis examines users' preference for short, generic queries and the extent to which observed search behavior is consistent with broad-to-narrow navigation. Users may initiate searches using broad terms (e.g., "laptop", "refrigerator", "Samsung") and subsequently narrow the product space through filters or query reformulation. The available aggregated data are used to characterize these patterns rather than to conduct formal hypothesis testing.

The analysis examines the proportion of generic queries and subsequent aggregate refinement and navigation actions. Device-level, traffic-source, and user-segment differences are not evaluated because these dimensions were not consistently available across the analytical dataset.

4. Results

4.1. Study 1: Search Results Page Enrichment and Search Performance

This analysis examines observed changes associated with enhancing the search results page (Search Display Page) on user behavior and key performance indicators. The analysis focuses on the high-frequency query "Samsung", which was recorded 6435 times over two consecutive months (Table 2).

Table 2. Search performance before and after the Search Results Page redesign for the query “Samsung”.

Month	Searches (Samsung)	Refinement Rate (%)	Purchases from Search	CR (%)	AOV (€)	Revenue (€)
September	3146	50	28	0.89	310	8680
October	3289	25	35	1.10	330	11,550

During the first period (September 2024), the search results page included only basic filtering options and lacked structured visual guidance. In the second period (October 2024), the page was redesigned to include category tabs (e.g., Smartphones, Smartwatches, Laptops), promotional banners, and enhanced filtering functionality.

First, the refinement rate decreased substantially, from 50% to 25%. This represents a 25-percentage-point reduction in refinement activity between the two observation periods. Interpretation of this change in relation to search friction, navigation, and interface design is considered separately in Section 4.4.

Second, the conversion rate increased from 0.89% to 1.10%, while search-driven revenue increased from €8680 to €11,550 and average order value rose from €310 to €330. These concurrent changes indicate improved commercial performance during the post-redesign observation period. Given the absence of randomization and a concurrent control group, the changes are interpreted as associations that coincided with the interface redesign rather than as causal effects attributable solely to the redesign.

Additionally, the average order value (AOV) increased from €310 to €330. This represents a €20 increase in AOV between the two observation periods. The available aggregate data do not identify the specific product-selection or decision processes underlying this difference.

Overall, the observed patterns indicate that the post-redesign period, characterized by structured navigation, visual elements, and advanced filtering, was associated with lower refinement activity and stronger commercial search performance. This pattern is consistent with prior evidence that search-refinement tools such as sorting and filtering can materially shape consumer search behavior in online environments [35].

Taken together, these observations address RQ1 by showing that the post-redesign period was characterized by lower refinement and higher conversion-related commercial metrics.

Finally, the observed patterns suggest that search-interface configuration is relevant to how users interact with search results, but the present data do not identify which individual interface component accounts for the post-redesign differences. The combined introduction of filtering tools, visual elements, and structured information architecture coincided with lower refinement activity and stronger commercial indicators during the second observation period. Because these components were introduced together and the analysis uses aggregated before-and-after data from a single retailer, the findings should be interpreted at the level of the combined interface configuration rather than as evidence that any specific element reduced user effort or improved usability.

4.2. Study 2: Visual Banners, User Engagement, and Search Performance

This analysis compares user interaction and commercial search metrics across two consecutive observation periods for the high-frequency query “iPhone”. The principal interface difference examined is the presence of a promotional visual banner during the second period (Table 3).

Table 3. Search performance before and after the introduction of visual guidance for the query “iPhone”.

Month	Queries (iPhone)	Banners' Clicks	CTR	CTR (%)	AOV (€)	Total Engagement (%)	CR (%)
April	10,264	0	3489	33.6	365	33.6	2.3
May	9965	2491	2985 (+1491)	29.9	387	44	2.7

Two consecutive periods were compared. In the first period (April 2025), the search results page did not include any visual banners, and users were presented only with organic product listings. During this period, 10,264 queries generated 3489 product clicks, corresponding to a product click-through rate (CTR) of 33.6%. The conversion rate reached 2.3%, while the average session duration on the search results page was 1 min and 42 s.

In the second period (May 2025), a visually prominent promotional banner was introduced, during the subsequent observation period. Although total queries slightly decreased to 9965, user interaction increased substantially. Product clicks decreased to 2985 (CTR: 29.9%), but the banner generated an additional 1491 clicks. As a result, total engagement increased from 3489 to 4476 interactions, representing an increase of approximately 28%, with overall engagement reaching 44%.

Furthermore, average session duration increased from 1 min and 42 s to 2 min and 27 s. The conversion rate rose from 2.3% to 2.7%, while average order value (AOV) increased from €365 to €387. Together, these figures document higher total interaction, longer session duration, conversion rate, and AOV during the banner-present period; their interpretation is considered separately in Section 4.4.

The banner accounted for 1491 additional interactions during the second observation period. The theoretical interpretation of this pattern in relation to visual attention and navigational guidance is developed in Section 4.4.

The observed before-and-after differences are descriptive and should not be interpreted as evidence that the banner itself caused the changes in engagement or transaction value.

Overall, Study 2 documents higher total engagement and stronger commercial metrics during the banner-present observation period.

Taken together, these observations address RQ2 by showing higher engagement and commercial search metrics during the period in which visual guidance was present.

4.3. Study 3: Preference for Generic Queries and the Broad-to-Narrow Search Behavior

This study describes the prevalence of generic search queries and the subsequent use of platform-provided refinement and navigation mechanisms.

The analysis is based on search data collected during the period from 2 September 2024, to 31 May 2025. Results indicate that approximately 76% of all queries were single-word or generic category-based terms (e.g., “laptop”, “iPhone”, “refrigerator”, “Samsung”). This distribution shows that short and generic formulations dominated the observed query set.

The observed sequence of generic query formulation followed by use of filters, categories, or other navigational tools is described here as a broad-to-narrow pattern; its theoretical interpretation is developed in Section 4.4.

In the available observational comparisons, periods with richer interface support—including filters, category tabs, and visual elements—coincided with lower refinement rates and, depending on the comparison, higher conversion-related metrics or longer session duration.

Periods with more limited interface support showed higher refinement activity in the available comparison data.

The theoretical relationship between these observed patterns and exploratory-search perspectives is considered in Section 4.4.

The present dataset does not provide a direct comparison between ranking-algorithm changes and interface changes; conclusions about their relative contribution therefore remain outside the scope of the empirical results.

Overall, Study 3 documents a predominance of generic queries together with observed use of platform-provided navigation mechanisms for subsequent refinement.

4.4. Interpretation of Results and Theoretical Implications

The findings of this research provide real-world observational evidence regarding on-site search behavior and commercial search performance within the studied e-commerce environment and can be interpreted in relation to key theoretical perspectives from the existing literature. Across the three analyses, the observed patterns are consistent with the relevance of interface design, visual guidance, and emerging AI-related search capabilities to the broader design of on-site search; however, the aggregated data do not permit causal attribution to individual interface features or direct inference about perceived usability, subjective user experience, or accessibility conformance.

First, the results indicate that Search Results Page (SRP) design is associated with observable differences in user behavior and commercial search performance. The post-redesign patterns observed in Study 1—particularly the lower refinement rate and higher conversion and revenue—are consistent with research showing that search costs, filtering mechanisms, and refinement tools can shape consumer search and platform outcomes [8,35]. These findings reinforce the view of on-site search as both a retrieval and navigation environment.

Second, the results show that the introduction of visual content coincided with higher observed user engagement and commercial performance. This pattern is consistent with established evidence that visual elements affect attention allocation and that digital design elements can shape online customer responses [6,37]. Within the present study, visual elements are therefore interpreted as complementary navigation cues rather than as isolated causal drivers of user behavior.

Third, the dominance of generic queries and the prevalence of broad-to-narrow navigation patterns identified in Study 3 are consistent with a role for information architecture and interface design in supporting exploratory search behavior. This interpretation aligns with research describing online search as an iterative process in which information needs evolve through interaction, learning, and refinement [36,42]. It also aligns with the “search-as-navigation” perspective adopted in this paper, while perceived usability itself was not directly measured.

Taken together, the findings support examining search-system design as a combination of algorithmic relevance, interface configuration, and visual and navigational support. In the present retail context, these dimensions provide a useful framework for interpreting the observed behavioral and commercial patterns, but the data do not establish an optimal or universally applicable search configuration.

Focusing exclusively on ranking accuracy is insufficient to meet modern user expectations. Instead, search systems must evolve into integrated, interactive environments that support exploration, decision-making, and personalization.

From a human-centered design perspective, the observed commercial and behavioral patterns should be interpreted alongside—but not as evidence of—usability and accessibility. The interface components examined in the studies, including filters, tabs, promotional

banners, and dynamically updated result areas, create interaction requirements concerning perceivability, operability, understandable feedback, and user control [14,16]. The present dataset cannot determine whether those requirements were satisfied. Thus, the practical implication is not that commercially stronger configurations are necessarily more usable or accessible, but that behavioral and commercial testing of search changes should be complemented by direct usability assessment and accessibility-oriented evaluation of the same interface components.

4.5. Practical Implications and Scope of Recommendations

The empirical results have practical relevance for e-commerce search management, but the recommendations should remain proportionate to the observational design and are best formulated as context-specific, testable design propositions. Within the studied retailer, Study 1 suggests testing combined Search Results Page configurations that provide structured navigation and refinement support, because the post-redesign period—characterized by category tabs, enhanced filters, and visual elements—coincided with lower refinement activity and stronger conversion-related metrics. Study 2 suggests testing visual guidance as a complementary search-interface element, because the banner-present period coincided with higher total engagement, longer session duration, conversion rate, and AOV. Study 3 suggests testing search architectures that support progressive refinement, because broad and generic queries were prevalent and users frequently relied on platform-provided refinement and navigation mechanisms. These propositions concern observable interaction and commercial outcomes; they do not establish that any individual interface element caused the observed changes or that the configurations improved perceived usability, subjective user experience, or accessibility. Accordingly, organizations should validate such propositions in their own retail context through controlled or staged interface testing and longitudinal performance monitoring, while evaluating usability and accessibility through appropriate user-centered and standards-based methods. The findings do not establish that the same configurations will produce equivalent outcomes across retailers, product categories, user populations, devices, or market conditions.

5. Limitations

This research presents several limitations. First, the analysis is based on data from a single large omnichannel e-commerce platform. Although the dataset captures substantial real-world search activity, the observed patterns may reflect platform-specific characteristics, market conditions, product mix, or brand-related factors; consequently, generalizability to other e-commerce contexts is limited. The findings should therefore be interpreted as evidence about search behavior and commercial performance within the observed retail environment rather than as universally generalizable effects.

The available behavioral data also did not include sociodemographic or individual-level characteristics such as age, education, digital literacy, prior e-commerce experience, or familiarity with online search environments. These characteristics may influence query formulation, refinement behavior, and users' ability to navigate search interfaces. Consequently, the observed behavioral patterns cannot be attributed to specific user segments, and future research should examine whether search behavior and responses to interface changes vary across demographic and experience-based groups.

Finally, because the analyses rely primarily on aggregated behavioral and commercial indicators and do not employ inferential hypothesis testing, the reported changes should be interpreted descriptively. Future work using user-level data, larger sets of queries, concurrent comparison groups, or appropriate inferential models could assess the robustness and statistical uncertainty of the observed patterns.

A further limitation concerns the scope of user-experience and usability measurement. The study relies on behavioral and commercial data generated through the retailer's operational analytics and does not include standardized usability instruments, such as the System Usability Scale (SUS) or User Experience Questionnaire (UEQ), nor qualitative or task-based methods such as user interviews, think-aloud protocols, controlled usability testing, eye-tracking, or heatmap-based observation. Consequently, the observed changes in refinement behavior, engagement, conversion, and other performance indicators cannot be interpreted as direct evidence of improvements in perceived usability, satisfaction, cognitive effort, or overall subjective user experience. Future research could combine behavioral and commercial analytics with standardized usability measures and qualitative user research to examine whether observed interaction patterns correspond to users' perceptions and experiences of the search interface.

The study also did not include a systematic accessibility evaluation or conformance audit of the on-site search interface. The implemented interface components were not assessed against WCAG 2.2 success criteria or the accessibility requirements of EN 301 549, and the available analytics do not identify whether users with disabilities encountered barriers when interacting with filters, tabs, banners, navigation controls, or dynamically updated search results [14,16]. Accordingly, the observed behavioral and commercial outcomes cannot be used to infer accessibility conformance or improvements in accessibility. Future research should complement behavioral analytics with systematic accessibility testing, including standards-based audits and evaluations involving users with diverse abilities, to determine whether search-interface interventions support equitable access alongside commercial and behavioral performance.

The observational before-and-after design introduces additional threats to internal validity that should be considered when interpreting the reported changes. Because the interface interventions were implemented in a live commercial environment without random assignment, a concurrent control condition, or experimental control over exposure, differences between the pre- and post-intervention periods cannot be attributed uniquely to the interface changes. Potential time-varying confounders include seasonality, promotional campaigns, changes in traffic volume or acquisition channel mix, shifts in product assortment, pricing and discount activity, inventory availability, and other concurrent changes to the e-commerce environment. These factors may independently affect search behavior, conversion, average order value, and revenue and may therefore contribute to the observed before-and-after differences. The study should consequently be interpreted as providing real-world observational evidence of temporal associations following interface changes rather than causal estimates of treatment effects. Future research could strengthen causal identification through randomized A/B testing, staggered rollouts, matched control periods or comparison sites, interrupted time-series designs, or difference-in-differences approaches where suitable longitudinal control data are available.

6. Conclusions

This research investigated the role of on-site search within a large-scale e-commerce environment, focusing on how interface design, visual content, and query and refinement patterns are associated with observable interaction patterns and commercial search performance.

Drawing on real-world search data and three complementary observational analyses, the findings provide evidence that on-site search functions as both a retrieval mechanism and a navigation component of the digital customer journey.

Specifically, the observed post-redesign period was characterized by lower refinement and higher conversion-related commercial metrics, while the period with visual guidance

showed higher engagement-related outcomes. The descriptive query analysis further revealed a strong prevalence of short, generic queries and patterns consistent with broad-to-narrow navigation.

Overall, the findings support examining on-site search as a combination of algorithmic relevance, interface configuration, and visual and navigational support. In e-commerce settings, the effectiveness of particular configurations should be evaluated within the relevant retail context using behavioral and commercial evidence alongside separate user-centered usability and accessibility assessment where those qualities are of interest.

From a managerial perspective, the results suggest that on-site search optimization can be associated with measurable differences in observable user engagement and commercial search performance. Organizations can therefore treat search as a strategic digital-commerce capability while evaluating interface changes through clearly defined behavioral and commercial indicators.

For future research, the integration of multichannel data and qualitative methods could provide deeper insights into user behavior. Furthermore, the adoption of natural language understanding (NLU) and conversational search systems represents a promising direction for addressing evolving user expectations. Stronger causal inference would require designs such as randomized A/B tests, staggered rollouts, matched comparison groups, interrupted time-series analyses, or difference-in-differences approaches, ideally combined with user-level data and broader sets of queries.

In conclusion, this research suggests that changes in on-site search interface design can coincide with meaningful behavioral and commercial performance differences. Because the evidence is observational and derives from a single retail context, these findings should be interpreted as real-world associations that motivate further controlled and user-level research rather than as definitive causal estimates.

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