# Investigating Characteristics of Non-click Behavior Using Query Logs[*]

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**Abstract.** Users' query and click behavior information has been widely used in relevance feedback techniques to improve search engine performance. However, there is a special kind of user behavior that submitting a query but not clicking any result returned by search engines. Queries ending with non-click make up a large fraction of user search activities, but few studies on them have been done in user behavior analysis. In this paper we investigate non-click behavior using large scale search logs from a commercial search engine. We analyze query and non-click behavior characteristics on three levels, i.e., query, session and user level. Query frequency, search engine returned results and category of information need are observed to be relative to non-click behavior. There are significant differences between post-query actions of clicked and non-clicked queries. Users' personal preference can also results in non-click behavior. Our findings have implications for separating queries which are handled well or not by search engines and are useful in user behavior reliability study.

**Keywords:** Non-click behavior, click-through log, query session analysis.

## 1  Introduction

User behavior analysis has played an important role in Web information retrieval. A variety of techniques based on user behaviors have been proposed and applied to improve search engine performance. These techniques mainly use query-click data as feedback to gain users' information need and relevance judgments of queries [1].

The optimal situation in Web search is that users submit queries and click a few results to satisfy their need. However, in real Web search process, click behavior doesn't happen certainly. In many cases the user doesn't click any result for the query. Non-click is a kind of special user behavior which may due to complex factors. For example, the results are too irrelevant to worth clicking, or the search engine returns no result so that click is impossible, or the user attains the goal from titles and

abstracts directly so that there is no need to click through. However, Non-click provides valuable information as well as click behavior for search engine optimization.

In this paper we make an empirical study on the characteristics of non-click behavior to investigate the factors affecting users' choice whether to click or not. This study is carried out on three levels based on large scale search logs of a commercial search engine. At first we analyze the features of queries which are without clicks under most of their appearances. Then we make comparative analysis of entire search process (referred as *session*) which originates with a clicked query or non-clicked query. On this session level, post-query actions are taken into account as potential interpretation and consequence of non-click behavior. On user level we focus on some different search customs of users who prefer to click results and rarely click results. From the investigation we find some relationship between non-click behavior and query, resource, user features. We propose to consider these non-click related factors in studies concerning relevance feedback and user reliability.

The rest of the paper is organized as follows. In Section 2 we review related work in user behavior analysis. Section 3 introduces the data we used in our log-based study. Section 4 describes the search features of three levels on which we focus. We present our findings in Section5. Section 6 is about conclusions and future work.

## 2   Related Work

A variety of research efforts have been made to acquire more knowledge about user behavior. Human-based techniques, such as eye-tracking was used in some studies to look into users' decision process, aiming at finding effectiveness of implicit feedback comparing with manual relevance judgments [2].  The advantage of this method is that we can observe what people are looking at before they click [3], but the disadvantages also exist in its unreal and highly limited experimental environment.

One of the most important methods in user behavior analysis is log-based study [4]. Downey's studies focused on the relationship of queries and destination URLs [5] and the difference between common and rare queries [6]. He also proposed many useful search features. By analyzing interaction style and domain information, two classes of users- navigators and explorers as well as advanced users are separated in [7][8][9]. Users' click and skip information also proves to be effective for query suggestion [10]. All these studies interpreted or modeled general user behaviors including query-click and web browsing, but not analyzed non-click behavior.

Recently user behavior reliability has seized people's attention. Studies about click reliability based on context of click behavior [11] and the reliability of one user [12] give us a wider view of user behavior study except for query-click data. Non-click is an important behavior in user search process, which may provide much information about the interaction between users and search engines, but has hardly been studied in previous work. We make a study of it from query, session and user level through search logs analysis, for a general impression on this special and interesting behavior.

## 3 Data

We use search logs collected anonymously by a commercial search engine from server-side to perform our study. First of all we deal with the noise in data. Entries of query submission generated by accidentally clicks of hyperlinks are abandoned; we select those log entries originating with user's active submission of a query. Each log entry describes an interactive action between search engines and users. It contains an identifier for the user, a timestamp for the action, some parameters indicating the attributes of the action, the URLs of referred page, current page and destination page.

From the logs we can get all queries and corresponding click or non-click information. We refer to each query submitted by users as a query request. Requests with the same query are put together for analysis of each unique query.

Then we mine sessions. A session refers to an entire search process with a series of interactions to address user's information goal [13]. In our method, we start a session with an user's query submission, and end it if the user makes no action to search engine over 30min or submits an irrelevant query to begin a new search process. We refer to the first query in a session as the *goal query*. When the user is not satisfied with the search engine returned results on the first page, he/she may slide down the list pages to find results or change the query through clicking query suggestion, query correction or re-writing query directly. We refer to all these actions as post-query actions. A session entry records the goal query and post-query actions as a search trail.

Finally we gather all the sessions by individual users through unique identifiers.

Table 1 shows the data on which we make our study of non-click from three levels. In figure 1 we give the long-tailed query frequency distribution of the data set. From the right figure we can see that the top 10% of queries with highest frequency cover 78.2% of all the requests.

**Table 1.** Users' search and click-through log data information

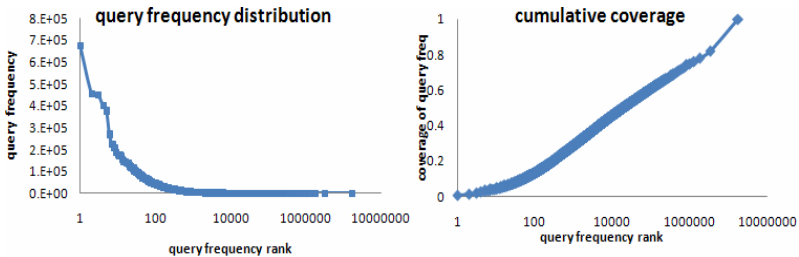| Request number | Unique query number | Total clicks | Session number | User number |
|---|---|---|---|---|
| 77,820,191 | 17,236,938 | 88,987,857 | 36,618,342 | 27,107,586 |



**Fig. 1.** Query frequency distribution and cumulative coverage. X-axis is query rank.

# 4   Non-click Analysis on Three Levels

## 4.1   Query Level Analysis

As there are many query requests with the same query but different click information, on query level, non-click behavior happens with a certain probability for each query. We define a metric namely *click ratio* to approximately describe the probability of a unique query with click. The lower *click ratio* is, the more frequent non-click behavior happens when users search this query.

$$click\ ratio = \frac{\#query\ request\ with\ click}{\#all\ the\ query\ request} \tag{1}$$

From Table 2 we can see there are most queries are in two extremes of *click ratio* (i.e. 0 or 1). Only 9.7% of queries are mixed clicked. Figure 2(a) shows more than 80% of these mixed queries are submitted only one or two times, on which click behavior is rather random. This reminds us *click ratio* of rare query is not reliable, so that we just select queries occurring more than three times. There are 1,269,868 unique queries meeting the need, which make up 7.4% of the total unique queries and cover 76.2% of all the query requests. Figure 2 (b) shows their click ratio distribution.

**Table 2.** Queries with different click ratio

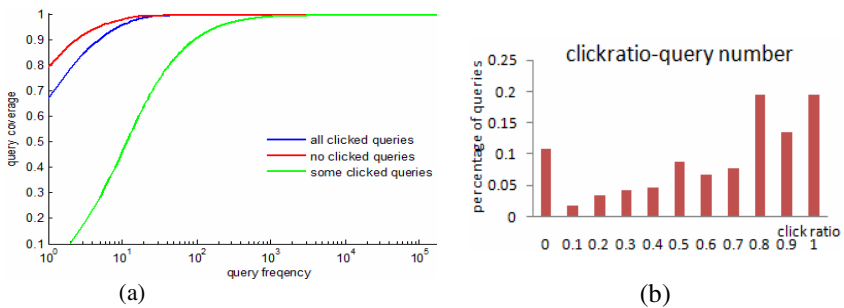|  | Number of queries | Query Frequency | Frequency of clicks |
|---|---|---|---|
| All clicked(ratio=0) | 8,095,348(**47%**) | 10,114,784(**13%**) | 22,448,698(**25.2%**) |
| Never clicked(ratio=1) | 7,459,583(**43.3%**) | 10,265,055(**13.2%**) | 0 |
| Mixed | 1,682,007(**9.7%**) | 57,440,352(**73.8%**) | 66,539,159(**74.8%**) |
| Total | 17,236,938 | 77,820,191 | 88,987,857 |



|   (a)   |   (b)   |
|---|---|

**Fig. 2.** (a) Cumulative coverage along with query frequency. (b) *Click ratio* distribution

We refer queries with *click ratio<=1/3, 1/3<click ratio<2/3*, and *click ratio>=2/3* respectively as *low-click queries, medium-click queries* and *high-click queries*. Features to be compared among the three are listed in Table 3.

We classify these queries into four categories: *navigational*, *sex/pornography*, *vanity search* and *the other*. *Navigational* queries are separated based on the Broder category [14] which assigns queries to be navigational, informational and transactional

(the latter two are usually treated as non-navigational). *Sex/pornography* queries are proved to be special in many aspects of user behaviors. *Vanity search* queries are also separated for the reason that they raised more and more attention by commercial search engines. Most of *the other* queries are traditional informational and transactional queries.

**Table 3.** Query features (per unique query)

| Query feature | Description of the feature |
|---------------|---------------------------|
| QF | Frequency of this query |
| RN | The latest number of results returned by the search engine |
| QL | Length of the query |
| FAT | Average time after query submitting until first action done |
| QC | Category of the query |

### 4.2  Session Level Analysis

Each session is a search process, in which rare queries are also maintained, since if they are omitted, the session may be incomplete. In order to state our comparative experiments, we define three data sets.

*Click Set* refers to the sessions whose goal query is with result clicks. That is to say, people begin the search process by submitting a query and clicking some results for this query. *Non-click Set* refers to the sessions whose goal query is without result clicks, while there may be clicks for other queries submitted after the first query. In these sessions there are post-query actions. *Non-action Set* refers to the sessions without out any post-query action. That is to say, after submitting the first query, the user doesn't do anything (of course he/she can look at the result list in the first page, but we can't know this action from the logs). The size of each set is shown in Table 4.

**Table 4.** Click Set, Non-click Set, Non-action Set

| | Click Set | Non-click Set | Non-action Set |
|---|---|---|---|
| Number of sessions | 21,808,194 (**59.6%**) | 6,133,755 (**16.7%**) | 8,676,393 (**23.7%**) |

A session contains the context of click behavior. We are actually interested in users' activities after they click or do not click results for the goal query. Two features of goal queries and four features of sessions are compared in our experiment as listed in Table 5. The post-query actions include result clicks, page down, query suggestion, query correction and query re-writing after the goal query. As a comparison, actions out of the goal query refer to those activities after the goal query is changed.

**Table 5.** Features on session level

| feature | Description of the feature |
|---------|---------------------------|
| G-FAT | Time after the goal query submitting until the first action done |
| G-QT | Time in the goal query |
| SQN | The number of queries in the session |
| AOQ | The number of actions out of the goal query |
| SPA | The percentage of different post-query actions in sessions |

### 4.3  User Level Analysis

Non-click behavior is relative to user's personality as the same query may be clicked by one user but not clicked by another. We use *user click ratio* to describe the probability of a user performing click action and estimate it with the proportion of sessions in Click Set in all the sessions of the same user. There is also data sparseness problem as with query level that most users only take one or two search process. We omit those users and use remaining 1,399,841 users for experiment. Three kinds of users are defined, i.e., high-click user (*user click ratio* < 1/3), medium-click user (1/3 <= *user click ratio* <= 2/3) and low-click user (*user click ratio* > 2/3) in Table 6.

**Table 6.** User click ratio partition

|  | High-click users | Medium-click users | Low-click users |
|---|---|---|---|
| Number of Users | 135,033 (**9.6%**) | 540,319(**38.6%**) | 724,489 (**51.8%**) |

We select four features listed in Table 7 to see how a user's preference in query description, effort for finding results, and time spent are related to non-click behavior.

**Table 7.** Features on user level (per user)

| feature | Description of the feature |
|---|---|
| AQL | Average query length of the user's search process |
| ASC | Average number of clicks in a session |
| ASA | Average number of actions in a session |
| AQT | Average time spent in the goal query |

## 5  Findings

In this section we present our findings of the investigation. We make comments on each feature and give summaries of the characteristics of non-click behavior.

### 5.1  Query and Non-click Behavior

( Ⅰ ) *QF.* We investigate the relationship of click ratio and query frequency, finding that queries with high frequency are tending to be with a high click ratio. The lower frequency does a query have, the higher probability it has to be with a ratio of 0.5, which is a random click ratio. Table 8 shows the two results.

**Table 8.** For different query frequency region, the percentage of *click ratio*

| ratio\freq | 1E+01 | 1E+02 | 1E+03 | 1E+04 | 1E+05 | 1E+06 |
|---|---|---|---|---|---|---|
| [0,1/3] | 22.65% | 19.97% | 16.96% | 27.73% | 13.95% | 0.00% |
| (1/3,2/3) | 20.87% | 22.32% | 21.69% | 16.22% | 19.45% | 6.67% |
| [2/3,1] | 56.47% | 57.71% | 61.35% | 56.04% | **66.60%** | **93.33%** |
| *0.5* | *10.53%* | *6.23%* | *4.63%* | *3.71%* | *2.95%* | *0.00%* |

( Ⅱ ) **RN**. Figure 3(a) shows for high-click queries, the typical RN is from $10^4$ to $10^6$. As a result, queries with RN in this range are more probable to have higher click ratio in Figure 3(b). By contrast, 8.5% of low-click queries have no resource at all.

In fact resource for the same query varies from time to time in web search environment. We count the resource of all non-click requests. Figure 3(c) indicates that about 15% of non-click requests happen in the condition of no resource.
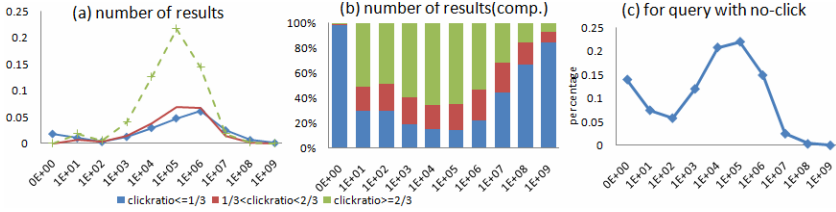


**Fig. 3.** (a) The distributions of RN feature of three kinds of queries. (b) The composition of click ratio for each RN bin. (c) The percentage of query requests with different RN.

(Ⅲ) **QL.** Query length is also distinctive in Figure 4(a). We can see that queries containing five to eleven characters (two to four words after segment) are more likely to be with higher click ratio, while the majority of low-click queries contain only three or four characters. Presumably when query is too short to understand the user's information need or too long for the search engine to find resource matching all parts of the query, bad results and non-click behavior may happen.

(Ⅳ) **FAT.** We can see from Figure 4(b) the trends of curves are the same while the curve of high-click queries is sharper during 0 to 30s, suggesting a preference to less time to make the first action. For 60% of queries, the average first action time is no more than 10 seconds. That is to say, people will rather quickly make a choice to click a result, change the query, turn to another page or leave the search engine, etc.
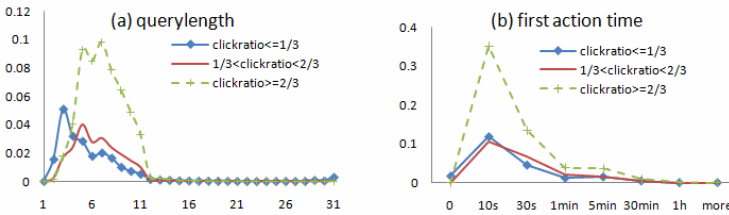


**Fig. 4.** (a) and (b) are the percentage of queries with different QL and FAT, respectively

( Ⅴ )**QC**. We find the category of a query has implicit influence on non-click behavior. Percentage of *sex/pornography* category is higher (5.6%) in high-click queries as shown in Figure 5(a). In *navigational* category 83% of queries have higher click ratio as Figure 5(b) shows. This result consists with our knowledge that navigational query is well handled.
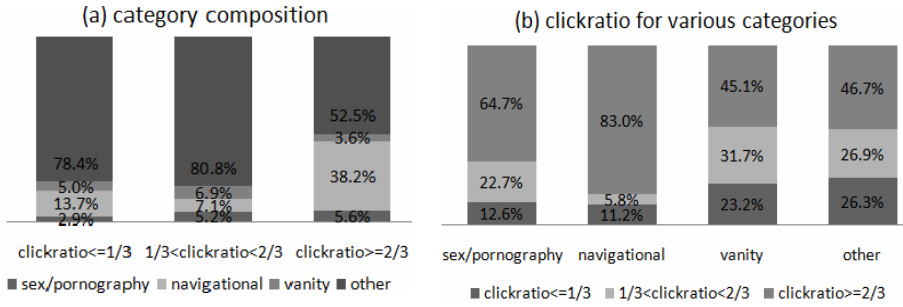
**Fig. 5.** (a) The percentage of categories in different click ratio region. (b) The percentage of click ratio in different category.

## 5.2 Non-click and Post-query Actions in Session

(Ⅰ) *G-FAT.* Consistent to the conclusions stated in *FAT* feature on query level, in over 82% of search process users make the first action in 10s. As Figure 6(a) shows, in Click Set about 80% of the first actions (e.g. clicking) happen in 10s, inflecting that the results are relevant to their information need. In Non-click Set and Non-action Set, there are a large part of goal queries which users make decisions (of course not to click) almost at first sight, so the results should be very bad for users. In Non-click Set there are also 20% of goal queries demanding a little longer time to make the first decision. For example, users scan the list from top to bottom or look at the query suggestions. In this situation the results are not so bad but not relevant enough to the query as users prefer to compare them even though they do not click on any of them.

(Ⅱ)*G-QT.* Time in goal query can reflect the effort users make to find results without changing the goal query, which has some relationship of the first action time as Figure 6(b). In No-action Set they are the same. In Click Set, except for the region of about 10s, there is an increase in region of 5min to 30min, since users will look into the clicked page and click several times to interact with the search engine. In No-click Set, typical time in goal query is from below 10s to 5min, since users may spend more time to read abstract and think about the results or slide down pages.
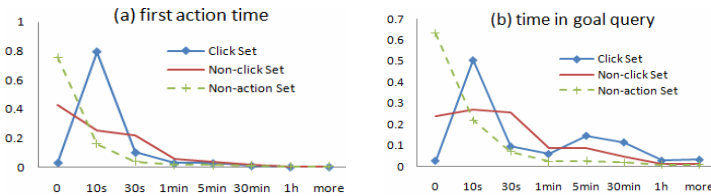


**Fig. 6.** (a) The G-FAT distribution of each set. (b) The G-QT distribution of each set.

(Ⅲ) *SQ.* As Figure 7(a) shows, in more than 90% of Non-click sessions the user will resubmit queries, while more than 60% of Click sessions contain only the goal query. That is a significant difference. About 40% of Non-click sessions change the query for one time, as this percentage of Click sessions is 19%.

We did not think users would submit so many queries (e.g. above 5) in a session, especially in Click Set, but the statistic is out of our expectation, indicating that click behavior does not mean satisfaction of users. The clicked result may be not relevant and even if the result is relevant, the user may still change the goal query to make it clearer, or move to another related query for more information. Anyway 90% of sessions contain no more than 9 queries, no matter the goal query is with click or not.

(IV) *AOQ.* Figure 7(b) shows the number of actions after changing the goal query. We can see that in Non-click Set, AOQ is much more than in Click Set. The most sessions will have two actions after changing the goal query, which may be a resubmission and another action on this query. This can also confirm the SQ feature. There are about 10% of all sessions contain more than eight queries, and here the percentage of AOQ>8 is about 30%, which is reconcilable.



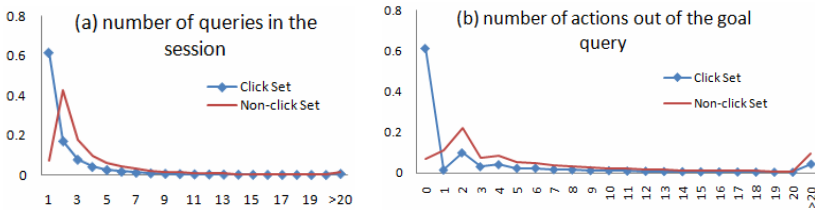**Fig. 7.** (a) The percentage of sessions with QN. (b) The percentage of sessions with AOQ.

(V) *SPA.* Figure 8 shows the proportions of five kinds of post-query actions. These actions are not totally mutually-exclusive so that the sum of proportions does not equal 100% for each set. In Click Set nearly 60% of sessions end up with clicks on the goal query, which consists with AOQ feature on the point that 61.4% of sessions in Click Set contain no actions out of the goal query. In Non-click Set this bar is not zero in that users may click some irrelevant things in the result page such as ad-links at the right of pages. In Non-click Set the percentage of query re-writing is 85.5%, meanwhile there is 15.9% of sessions with query suggestion. These can indicate that in Non-click Set users are not satisfied with the goal query performance. Most of users prefer to reorganize the query by themselves and sometimes rely on query suggestions.

When users don't click any result on the first page, they may move down to another page or change the query. We compare SQ and AOQ features between those sessions with and without page down in Non-click Set.

As shown in the Figure 9(a), if users slide page down, about half of them will not resubmit queries any more. The results in Figure 9(b) also support this as 48.7% of sessions with page down have no actions out of the goal query. Compared with Fig. 7 we find that the sessions with page down in Non-click Set are more similar to sessions in Click Set in user behaviors. This may because if people would like to look at next page of result lists, the results hold a little relevance to users' information goal on some degree or users prefer spending more time in looking for proper results. In fact, users are mostly too lazy to look at more than one result page list. Thus the proportion of page change action is no more than 5% and the features of Non-click Set are mainly represented by those sessions without page down.
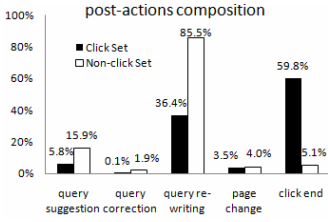
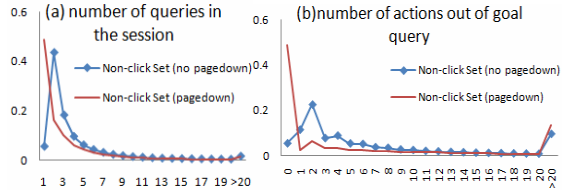**Fig. 8.** Comparison on the post-actions (Click vs. Non-click)

**Fig. 9.** the QN feature, OQA feature in comparison between sessions in Non-click Set with or without page down

From the analysis above, we can derive the impression that Non-action Set on the whole is a little better than Non-click Set on the first action time and time in query (see Fig. 6). This may lie in that non-action behavior sometime can mean very well-done cases such as queries about *the weather of tomorrow, what day is Father's Day* for which the search engine may give answers in the title or abstract of top results. However, if users do not click any result in the goal query but have more actions in the search process, it is probable that the results are not satisfying. In this non-click situation, the features of post-query actions are similar to those with clicks on goal query if users choose to look at other result pages except for the first page (see Fig. 9).

### 5.3  Non-click and Users' Click Preference

The comparative results of four features on user level are shown in Figure 10.

In Figure 10(a), AQL of medium-click and high-click users is similar. They prefer to use four to seven characters to describe their information goal while low-click users have a certain proportion of using two or three characters. As to AQT in Figure 10(b), the three curves are all double-humped but relative proportions are different. On the whole low-click users spend less time than the other two kinds in a query.

The ASC and ASA features are measured on the whole of users. About 5% of all users never click anything in each session in Figure 10(d). Users would not like to click too many results in a search process in that they want to find answers through the search engine as soon as possible. About 87.3% of users click no more than 6 times in a session on average. The ASA in Figure 10(c) also supports the idea that low-click users do not make much effort in addressing their information need.

Non-click behavior may due to users' habit that they do not like to click more results, or bad cases of returned results which are caused by many factors including their improper organization of queries and other inexperienced interactions. Here we do not make individual analysis of the users so that we can not conclude which users are experts. But we show the three kinds of users are distinguishing in several aspects of user behaviors. These findings convince us we should make a difference of them in user behavior analysis, not only from their retrieval interests and query content, but also from their click behaviors. An easy case supporting this idea can be that there is no need to release ads for users who rarely click results.
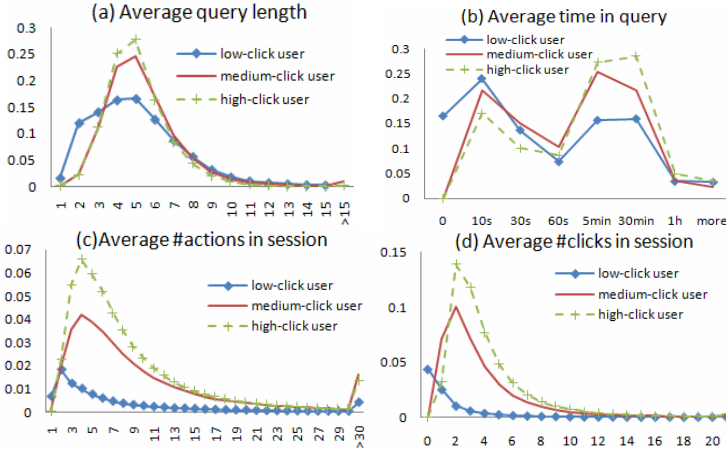
**Fig. 10.** Comparisons of (a)AQL, (b)AQT, (c)ASA, (d)ASC among different groups of users

## 6 Conclusions and Future Work

In this paper we present a log-based study on three levels to investigate the influential factors of non-click behavior. We define click ratio of queries and users, and separate sessions by non-click behavior on the goal query. We make a comparative analysis of features concerning various aspects including query, click, action and time. The main conclusions are listed as follows:

(1) Non-click behavior has much relationship with rare queries and resources. Query categories also have potential effect on it as navigational queries usually have a higher click ratio.
(2) Non-click behavior should be treated differently according to the post-query actions. Sessions with post-query actions have different characteristics from those without post-query actions, as the non-action sessions may include extreme satisfying cases. The sessions without clicks on goal query but with page down are more similar to those with clicks.
(3) It is important to distinguish user groups according to their click behavior in user related studies and applications, such as user reliability, browsing models and ads click prediction.
(4) Users will make judgments and do the first action in very short time after getting the search engine returned results. In most situations it is no more than 10s. This is an additional conclusion derived in our study.

The investigation is among the first to give a general insight on non-click behavior. Non-click is a special but frequent behavior in user search process, which implicates valuable information for Web search optimization. In the future, we will make a deep analysis of result relevance and user satisfaction with non-click behavior. Further studies focused on specific aspects we proposed in this paper for techniques of non-click modeling can also be done.

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