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# Satisficing and the Use of Keyboard Shortcuts: Being Good Enough Is Enough?

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†Piet Westendorp was the initiator of the research reported in this article, but sadly did not live to see its completion. The first and third author dedicate this article to his memory.

**Keyboard shortcuts are generally accepted as the most efficient method for issuing commands, but previous research has suggested that many people do not use them. In this study we investigate the use of keyboard shortcuts further and explore reasons why they are underutilized by users. In Experiment 1, we establish two baseline findings: (1) people infrequently use keyboard shortcuts and (2) lack of knowledge of keyboard shortcuts cannot fully account for the low frequency of use. In Experiments 2 and 3, we furthermore establish that (3) even when put under time pressure users often fail to select those methods they themselves believe to be fastest and (4) the frequency of use of keyboard shortcuts can be increased by a tool that assists users learning keyboard shortcuts. We discuss how the theoretical notion of 'satisficing', adopted from economic and cognitive theory, can explain our results.**

*Keywords: graphical user interfaces; graphics input devices; text input; HCI theory, concepts and models; empirical studies in HCI*

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## 1. INTRODUCTION

Keyboard shortcuts, also sometimes called keyboard accelerators or hot keys, are keystroke combinations for issuing commands in a computer application. For example, the keyboard shortcut for copying an object in Microsoft Windows applications is usually 'Ctrl+C'.

It is often agreed that keyboard shortcuts are a way for expert users to reach higher levels of efficiency, without compromising the learnability for novel users (Dix *et al.*, 2003; Lane *et al.*, 2005; Nielsen, 1993). Several studies have indeed shown the performance advantage of keyboards shortcuts over toolbar icons and traditional menu structures (Lane *et al.*, 2005; McLoone *et al.*, 2003; Odell *et al.*, 2004). Yet, it seems that even expert users often do not use the available shortcuts (Lane *et al.*, 2005; Peres *et al.*, 2005), with the self-reported use of keyboard shortcuts typically being around or less than 10% of the time in Lane *et al.* (2005). Similar results are found in other areas of computer use, namely that even experienced users still use inefficient strategies (Bhavnani and John, 1997).

Given the observations that users are frequently inefficient in their use of computers some researchers have taken it up as a goal to improve this efficiency by, for example, training users to use more efficient strategies (Bhavnani *et al.*, 2001) or encouraging users to use shortcuts (Lane *et al.*, 2005). However, before formulating implications for user training or interface design, more investigation into why people make little use of keyboard shortcuts is useful.

In this study, we explore a set of explanations for why people infrequently use keyboard shortcuts. We first study the frequency of use and knowledge of keyboard shortcuts and various other methods for issuing commands, adopting a methodology that we feel prevents certain problems and confounds we identify in previous studies concerning keyboard shortcut use. We explore to what extent lack of knowledge of keyboard shortcuts can account for the results we found. Next, we introduce a condition in which maximal efficiency is encouraged by giving users the instruction to complete an assignment as fast as possible. Lastly, we explore the effect of a tool that assists users learning keyboard shortcuts.

We discuss our results, and argue that our results can be explained by the notion of satisficing behavior. Finally, we complete the article with the implications of our findings and suggestions for future work.

## 2. RELATED WORK

In this section we look at previous work regarding the use of keyboard shortcuts as well as studies and theories concerning inefficient behavior and computer use in particular.

### 2.1. Use of keyboard shortcuts

Several studies have investigated underlying causes of the (lack of) use of keyboard shortcuts. For example, no relationships have been found between age, typing abilities, familiarity with computers and the use of keyboard shortcuts (Peres *et al.*, 2005). A relationship that has been found several times is between hours per week someone uses a computer and the use of keyboard shortcuts (Peres *et al.*, 2004, 2005).

Peres *et al.* (2004) investigated the impact of social factors on keyboard shortcut usage. A strong relationship was found between whether users are in a working environment with people who are keyboard shortcut users and whether the respondents were keyboard shortcut users themselves. The authors conclude that 'those who use [keyboard shortcuts] are more likely to have people around them that use [keyboard shortcuts]'.

Grossman *et al.* (2007) successfully address the lack of knowledge of keyboard shortcuts by manipulating feedback in the menu to make keyboard shortcuts more learnable. The authors also increase the cost associated with menu selection. They find that this significantly increases the use of keyboard shortcuts.

### 2.2. Inefficient computer use

Many researchers have identified that computer users frequently use inefficient strategies. For example, Bhavnani and John (1997) found that even experienced computer users still use inefficient strategies. With *inefficient strategy* the authors mean a way of performing a complex task (which is composed of combining several functions) which could have been done faster and/or with fewer operations. Carroll and Rosson (1987) observe that '[computer] skill tends to asymptote at relative mediocrity'. They label this phenomenon the 'paradox of the active user'. Users lack the motivation to invest time in learning new strategies, even if their current strategies are inefficient.

Bhavnani and John (2000) give several possible explanations for this inefficient usage. First of all, the efficient strategies might not be known. Secondly, the efficient strategies might be known, but not used. This might be because efficiency is not a goal for the users. Nielsen and Levy (1994) observed that even if a certain way of using a system objectively improves performance this does not necessarily mean that the users (subjectively) prefer to use it this way. Also, the strategies might not be more efficient after all because there are higher cognitive costs involved, like when the supposedly more efficient strategy is actually a very counterintuitive one. The generation of more efficient strategies has also been found to relate to the task that is being performed: Charman and Howes (2003) find that the cognitive demands related to the task at hand and the iterative nature of typical computer-based tasks negatively affect the generation of more efficient strategies. Finally, prior knowledge might dominate performance. Breaking your habits is difficult and takes a lot of (cognitive) effort.

## 3. EXPERIMENT 1: USE AND KNOWLEDGE OF KEYBOARD SHORTCUTS

The goal of Experiment 1 was to assess the frequency of use of various methods to issue commands, such as keyboard shortcuts, toolbar icons and users' knowledge of keyboard shortcuts.

Several previous studies have explored the relative use of keyboard shortcuts. For example, Lane *et al.* (2005) and Peres *et al.* (2005) asked participants to specify what percentage of time they used various methods to issue certain commands. They found that even expert users infrequently use the available keyboard shortcuts.

However, self-reports, which are used by Lane *et al.* (2005) and Peres *et al.* (2005), are not an accurate measure of actual computer use (Mikkelsen *et al.*, 2007). Several memory errors can undermine the accuracy of self-reports (Tourangeau, 2001). First of all, the encoding of the events into memory might fail. If an accurate representation of the event is never formed or is too superficial, retrieval also becomes difficult, or even impossible. Secondly, other events occurring after the original experience might distort the representation of the experience. Thirdly, even if the information is encoded and stored properly, retrieval errors may occur; one simply cannot remember it. Lastly, when information is recalled, people might wrongly fill in the gaps or otherwise distort the memory, and even 'remembering' events that never happened may occur (so-called false memories).

Lane *et al.* (2005) and Peres *et al.* (2005) asked participants to specify what percentage of time they used various methods to issue certain commands. In this case especially the first and fourth aforementioned types of memory errors seem likely to occur. Many mundane activities take place without much conscious awareness of how the behavior runs off (Roediger, 1990). For people who use a computer on a regular basis it seems unlikely that they are consciously aware of all the steps they take to, for example, save a document, open a document or copy a piece of text. Therefore, asking them about how they perform these actions might not generate accurate answers. In other words, 'one potential source of error in retrospective reports is that the respondent never really knew the answer in the first place' (Tourangeau, 2001, p. 33). This raises doubt about the validity of using self-reports to measure keyboard shortcut use.

In this experiment, we measure the frequency of use of various methods to issue commands. We also assess the knowledge of keyboard shortcuts. We adopt a methodology that particularly aims to prevent the aforementioned issues we identify in previous experiments. We study the use of 13 out of the 14 commands in Microsoft Word that were also studied in Lane *et al.* (2005); open, new, save, copy, cut, paste, undo, redo, find, spell check, bold, italic and underline.

### 3.1. Method

The experiment consisted of two main parts. In one part participants were given specific instructions on which tasks to perform on a given text document. Participants were, for example, instructed to add formatting to certain parts of the text, perform a spell check and copy a sentence to a new document. In these assignments, if performed error-free by the participants, all 13 commands under investigation would be issued at least once: bolding would be issued four times, pasting three times, cutting two times, italicizing and underlining twice each and all the other commands once. The text used for this part of the experiment was an existing text about one of the Bachelor degree programs at the Eindhoven University of Technology adopted from the website of the Eindhoven University of Technology. The text was one page in length. The second part of the experiment was a writing task where participants were asked to write a 150-word essay in Microsoft Word about their (former) education. Participants were explicitly encouraged to use formatting, such as bolding, italicizing and underlining. As participants might be confused about certain terminology if they were accustomed to using the Dutch version of Microsoft Word (as all participants were Dutch native speakers), the assignments were given in both Dutch and English.

#### *3.1.1. Software*

The English version of Microsoft Word 2003 was used. The toolbars were configured in such a way that all icons for the 13 commands were visible on the toolbar by default. Logging software was used to record all actions performed by the participants in an unobtrusive manner.

#### *3.1.2. Design and procedure*

The order of the two parts (the assignments and the writing task) was counterbalanced, with half of the participants performing the assignments first and half of the participants doing the writing task first. The questionnaire was always administered last. Participants were seated in individual rooms and were not able to communicate with each other. The experimenter was present in an adjacent room. All instructions, assignments and questionnaires were presented to the participants on the computer screen. In total, the experiment, including filling out the questionnaires, took about 15–30 min to complete.

#### *3.1.3. Questionnaires*

Various demographics of the participants were gathered by means of a questionnaire. The questionnaire consisted of two parts. In the first part of the questionnaire, participants were asked about their age, gender, number of hours per week they use a computer, both work and private, and number of hours per week they use Microsoft Word, both work and private. In the second part, participants were asked to enter the keyboard shortcuts in Microsoft Word for the commands studied. Participants were instructed to leave the answer blank if they did not know the answer and they were requested not to look up the answers in Microsoft Word or any other application. Compliance with these instructions was verified using the logging software.

#### *3.1.4. Participants*

Forty people, most of them students at the Eindhoven University of Technology, naïve about the goal of the experiment, participated in the experiment. Of those, 23 were males and 17 were females. Age ranged from 17 to 39 years with an average of 23.6 years. The number of hours per week they used a computer, both work and private, ranged from 10 to 72 with an average of 33.0, and number of hours per week they used Microsoft Word, both work and private, ranged from 0 to 25 with an average of 10.3. The experiment was undertaken with the consent of each participant. Participants were paid 3.50 euro for their participation.

### 3.2. Results and discussion

This section is divided into two parts. First, the frequency of use of keyboard shortcuts and other methods is analyzed, to assess whether keyboard use is indeed as rare as previous studies suggest. Next, the knowledge of keyboard shortcuts is examined and we report on how well a lack of knowledge can explain the underutilization of keyboard shortcuts.

#### *3.2.1. Use of keyboard shortcuts*

On average, participants used the keyboard shortcut during the assignments in Microsoft Word for 46.9% of the commands ($SD = 30.0\%$). An overview per command can be seen in Table 1. In Table 1 some groups of functions with nearly

**Table 1.** Percentages the various methods were used to issue commands by the participants in Experiment 1.

| | | Method | | | |
|---|---|---|---|---|---|
| Command | $n$ | Keyboard shortcut | Toolbar icon | Menu | Right mouse button |
| Open | 40 | 2.5 | 47.5 | 50.0 | |
| New | 40 | 10.0 | 87.5 | 2.5 | |
| Save | 40 | 25.0 | 67.5 | 7.5 | |
| Cut | 64 | 71.8 | 7.7 | | 20.5 |
| Copy | 40 | 77.5 | 5.0 | | 17.5 |
| Paste | 104 | 83.8 | 2.5 | | 13.7 |
| Undo | 40 | 60.0 | 35.0 | 5.0 | |
| Redo | 31 | 22.6 | 64.5 | 12.9 | |
| Find | 39 | 89.7 | 2.6 | 7.7 | |
| Spell check | 38 | 10.5 | 31.6 | 57.9 | |
| Bold | 155 | 53.1 | 46.9 | | |
| Italic | 76 | 56.2 | 43.8 | | |
| Underline | 79 | 47.5 | 52.5 | | |
| Mean | | 46.9 | 38.0 | 11.0 | 3.9 |

**Table 2.** Knowledge of keyboard shortcuts and the percentage of participants who know the keyboard shortcut, and did not use it in Experiment 1.

| | % participants | |
|---|---|---|
| Command | Knows keyboard shortcut | Knows keyboard shortcut, and did not use it |
| Open | 52.5 | 49.7 |
| New | 52.5 | 44.7 |
| Save | 85.0 | 60.0 |
| Cut | 82.5 | 10.3 |
| Copy | 97.5 | 20.5 |
| Paste | 90.0 | 20.0 |
| Undo | 77.5 | 20.0 |
| Redo | 37.5 | 17.3 |
| Find | 90.0 | 5.0 |
| Spell check | 17.5 | 7.0 |
| Bold | 80.0 | 28.7 |
| Italic | 82.5 | 26.2 |
| Underline | 77.5 | 30.0 |

identical frequency distributions over the various methods that were used can be identified. Bolding, italicizing and underlining show approximately the same distribution over the various methods that were used, as do cut, copy and paste. This is not surprising as these are quite similar commands. Overall, what is the most popular method varies greatly between the different commands. Whereas opening a document is hardly ever done using the keyboard shortcut, the find command is almost always issued using the keyboard shortcut.

There was no significant difference between the keyboard shortcuts use of the group that did the assignments in Microsoft Word first and the group that did the writing task first (Mann–Whitney $U$ test, $P > 0.2$).

No significant correlations were found between the use of keyboard shortcuts and either the number of hours per week participants used a computer ($r_s = 0.097$, $P > 0.5$) or the number of hours per week participants used Microsoft Word ($r_s = 0.019$, $P > 0.9$). In some previous studies, a (weak) correlation was found between hours per week someone used a computer and the use of keyboard shortcuts (Peres *et al.*, 2004, 2005). On the other hand, in the study by Lane *et al.* (2005), no significant correlations between the hours per week the participants used a computer or the hours per week they used Microsoft Word and the use of keyboard shortcuts were found. There are several possible explanations for why, at best, a weak correlation between computer use and the use of keyboard shortcuts is found: (1) the correlation between computer use and the use of keyboard shortcuts is weak, and therefore hard to detect, and (2) how often someone uses a computer is hard to measure using self-reports. We note that the absence of a correlation in the current study is not due to a restricted range, as the hours per week the participants used a computer showed a wide range, varying from 10 to 72 h per week.

#### 3.2.2. *Knowledge of keyboard shortcuts*

On average, participants knew 71.0% ($SD = 23.7\%$) of the 13 keyboard shortcuts (also see Table 2). The keyboard shortcut for copy was best known; 97.5% of participants knew it. Keyboard shortcuts for certain other commands are not that well known, for example, only 37.5% of the participants knew the keyboard shortcut for redo and 17.5% for spell check. Our results also show that if a person knows a keyboard shortcut this does not guarantee that he/she will use it. For example, out of the participants who did know the keyboard shortcut for opening a document, the large majority did not use it (see Table 2). In all, the lack of knowledge of the appropriate keyboard shortcuts cannot fully account for the results concerning the low frequency of use of the keyboard shortcuts.

### 3.3. Conclusion

Experiment 1 confirms early findings that people frequently do not use keyboard shortcuts to issue commands, without being subject to the same criticisms or reservations as earlier studies. However, some refinement of statements regarding the use of keyboard shortcuts seems appropriate: some commands are issued using the keyboard shortcut quite commonly, while for other commands the keyboard shortcut is hardly ever used. Also, the percentage of usage that we find is higher than estimated in previous studies, albeit still that more than 50% of the commands are not issued by a keyboard shortcut. Finally, we find that the lack of knowledge of keyboard shortcuts cannot fully account for the limited use of them.

## 4. EXPERIMENT 2: EFFICIENCY AND TIME PRESSURE

Experiment 2 sets out to investigate several reasons why people might not use keyboard shortcuts: (1) they do not care to be as fast as possible in their computer use and (2) they may not know that keyboard shortcuts are typically faster than other methods.

As noted by Bhavnani and John (2000), one of the reasons why people do not use the most efficient method is because they do not care to be as efficient as possible. In Experiment 2, we introduce a condition with time pressure, so that participants are encouraged to use the most efficient method. If, under time pressure, the use of keyboard shortcuts increases significantly compared with 'normal' conditions, it implies that users are aware of the higher efficiency of keyboard shortcuts but do not care about this higher efficiency enough to start using them in day-to-day use. On the other hand, if we find that time pressure does not significantly increase the use of keyboard shortcuts, this could be adequately explained by the fact that a person holds the belief that another method rather than the keyboard shortcut is the fastest method. Therefore, we also study beliefs about the most efficient methods.

### 4.1. Method

To study the effects of time pressure on the frequency of use of various methods the same 13 commands in Microsoft Word from Experiment 1 were used (open, new, save, copy, cut, paste. undo, redo, find, spell check, bold, italic and underline).

The participants were given the same assignments in Microsoft Word as the assignments in Experiment 1, but not the writing task. However, this time they were instructed to complete the assignments as fast as possible. A timer was added to each of the windows describing an assignment, so as to constantly remind the participants that the time was running and to implicitly suggest that the time it took to complete the assignments was being recorded. To prevent the participants from feeling unnecessarily rushed while reading the assignments themselves (with the risk of introducing errors in reading), the timer was not started until the participant navigated away from the window with the assignment. The timer was reset after each assignment.

#### *4.1.1. Software*

Microsoft Word was used, as in Experiment 1. For specifics about the configuration of Microsoft Word, refer to the Software subsection in the Methods section of Experiment 1. Logging software (identical to the software used in Experiment 1) was used to record all actions performed by the participants in an unobtrusive manner.

#### *4.1.2. Design and procedure*

Participants were seated in individual rooms and were not able to communicate with each other. The experimenter was present in an adjacent room. All instructions, assignments and questionnaires were presented to the participants on the computer screen.

The participants in Experiment 2 also completed Experiment 3 (described later), immediately after they did Experiment 2. The rationale for not randomizing the order of the two experiments was 3-fold. First, it seemed better to start with the experiment where there was time pressure to prevent effects of fatigue. Secondly, the participants in the experimental group in Experiment 3 (see Section 5) might get a 'hunch' that the experiment was about keyboard shortcuts, which could have affected their behavior in Experiment 2 had the order been reversed. Thirdly, even if they were not consciously aware of this last point, keyboard shortcuts might have become more salient for the participants for the experimental group in Experiment 3, possibly leading them to use more keyboard shortcuts in the assignments in Experiment 2. It should be noted that the results of Experiment 1 did not show that using the computer for a slightly longer period of time affects the use of keyboard shortcuts. In that sense, not randomizing the order of the two experiments is not expected to affect the results in any way. The two experiments, including filling out the questionnaires, took about 30–45 min to complete.

#### *4.1.3. Questionnaires*

After completing Experiments 2 and 3, participants were given several questionnaires. One questionnaire was the same as the questionnaire about keyboard shortcuts used in Experiment 1. Again, participants were asked whether to enter the keyboard shortcuts in Microsoft Word for the 13 commands studied. Extra emphasis was given to the fact that these questions applied to Microsoft Word, as, this time, participants had also been using another computer program (the graphical editor GLIPS in Experiment 3).

In the second questionnaire, participants had to choose which method they thought was fastest for them for copying a piece of text, opening a new document, and making a piece of text bold in Microsoft Word. These three commands were chosen, because it was shown in Experiment 1 that they differ greatly in terms of which methods the participants used (see Table 1). For the question about the copying command, response options were the keyboard shortcut, the toolbar icon, right mouse button, the menu or other (to be specified by the participant). For the questions about opening a new document and the bolding command, response options were the keyboard shortcut, the toolbar icon, the menu or other (to be specified by the participant). Two different orderings of these questions were used, each ordering presented to half of the participants in each condition.

In the last questionnaire, participants were asked about their age, gender, number of hours per week they use a computer, both work and private, and number of hours per week they use Microsoft Word, both work and private.

*4.1.4. Participants*
In total, 42 people, most of them students at the Eindhoven University of Technology, naïve about the goal of the experiment, participated. The results of one participant were excluded from the data because this person already participated in Experiment 1. Another participant was unable to complete the experiment and the results of this person were not usable for further analysis. Of the remaining 40 participants, 29 were males and 11 females. Ages ranged from 18 to 47 years with an average of 25.4 years. Number of hours per week they used a computer, both work and private, ranged from 7 to 100 with an average of 32.2 and number of hours per week they used Microsoft Word, both work and private, ranged from 0 to 25 with an average of 5.9. The experiment was undertaken with the consent of each participant. Participants were paid 5 euro for their participation.

### 4.2. Results and discussion

In this section, we examine the effect of time pressure on preferred methods to issue commands, by comparing behavior of participants when under time pressure to the behavior of participants in Experiment 1, where there was no time pressure. Next, the behavior under time pressure is compared with participants' views on which method they think is fastest.

*4.2.1. Effects of time pressure*
On average, participants in Experiment 2 used the keyboard shortcut for 41.5% ($SD = 26.1\%$) of the commands during the assignments in Microsoft Word. In Experiment 1 the mean was 46.9% ($SD = 30.0\%$). This difference is not significant (Mann–Whitney $U$ test, $P > 0.2$), suggesting that time pressure has no effect on keyboard shortcut usage. However, a fair comparison between the use of keyboard shortcuts in Experiments 1 and 2 needs to take the knowledge of keyboard shortcuts into account. After all, if someone does not know the keyboard shortcut for a command, then he/she cannot use it. It was indeed found that participants in Experiment 2 knew slightly fewer keyboard shortcuts than participants in Experiment 1 (71.0% in Experiment 1, 55.0% in Experiment 2, Mann–Whitney $U$ test, $P < 0.05$).[1] However, even when this difference in knowledge of keyboard shortcuts is accounted for, by analyzing the keyboard shortcut use of only the participants that knew the keyboard shortcut, no significant difference in the use of keyboard shortcuts between the participants in Experiments 1 and 2 can be found. Hence, there is no evidence that the instruction to complete the assignments as fast as possible has any effect on the frequency with which the participants are using the fastest method (i.e. keyboard shortcuts). However, this does not exclude the possibility that a participant is convinced that he/she is using the fastest method (i.e. participants might not think the keyboard shortcut is the fastest method).

*4.2.2. Beliefs about efficiency*
To test if participants were not using keyboard shortcuts under time pressure because they believe other methods than keyboard shortcuts are faster, participants were asked to indicate which method they think is fastest for them for issuing the following three commands in Microsoft Word: copying a text, opening a new document and bolding a text. The answers given are summarized in Fig. 1. The results show that subjective views of which method is fastest differ per command. Also, keyboard shortcuts are not always believed to be the fastest method (10, 65 and 40% of participants indicated another method than the keyboard shortcut is fastest for them for copying, opening and bolding, respectively). We compare these answers to what participants actually did in the assignments in Microsoft Word when given the instruction to complete the assignments as fast as possible. These results are also shown in Fig. 1. The results show that the participants often failed to use the method that they believe is fastest for them, even when they are under time pressure. Overall, 13, 60 and 21% of participants used another method than the one they indicated is fastest for them for copying, opening and bolding, respectively. For example, for the copy command, 13% of the participants indicated that the keyboard shortcut is the fastest method for them, but used either the toolbar icon or the right mouse button when given the instruction to complete the assignment as fast as possible. For opening a document 33% of the participants used the toolbar icon or the menu while they indicated the keyboard shortcut is fastest for them (only one participant who indicated the keyboard shortcut is fastest also used it). Finally, 38% of the participants used the menu for opening a document, while they indicated that either the toolbar icon or the keyboard shortcut is fastest for them.

### 4.3. Conclusion

The results of Experiment 2 show that participants do not use more shortcuts when under time pressure. This can partly be explained by the fact that some users do not consider the keyboard shortcut to be the fastest method to issue a command, though opinions differ between different commands. However, when put under time pressure, participants still frequently use another method than the one they indicate is fastest for them.

## 5. EXPERIMENT 3: KEYCUE

Traditionally, keyboard shortcuts are displayed next to the respective commands in the menu structure at the top of the

[1] Here, we only examine the participants in Experiment 2 who did not have access to the Keycue function in Experiment 3, as the participants who had access to Keycue in Experiment 3 might have learned some keyboard shortcuts during the experiment.

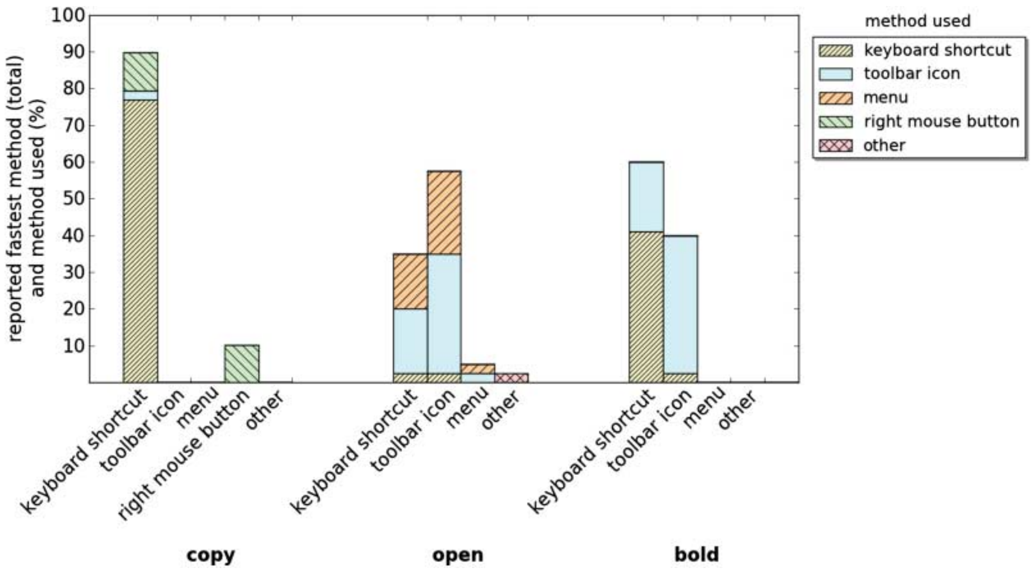


**Figure 1.** Percentage of participants that reported a method as being fastest for them to issue a command and the use of these methods when given the instruction to complete assignments as fast as possible (Experiment 2).

user interface. Grossman *et al.* (2007) propose that users often ignore this information, because when the menu is open, users already have access to the command in the drop-down menu. Therefore, the information is ignored, and the keyboard shortcut remains unlearned. In their study aimed at assisting the learning of keyboard shortcuts, the authors manipulate feedback in the menu to make shortcuts more learnable. The authors examine techniques which, among others, should stimulate *incidental learning*, where the learning is a by-product of completing tasks. They achieve this by manipulating the menu cost and feedback. For example, one technique demonstrated by the authors to be effective is to disable the menu item such that the command is not invoked, while the relevant keyboard shortcut briefly flashes, and another effective technique is to provide auditory feedback by playing the command name and the associated keyboard shortcut whenever the command is invoked.

While the techniques by Grossman *et al.* (2007) are promising, they still require the user to go through the menu structure, which is slow. Some of the techniques might also annoy users who simply do not want to learn keyboard shortcuts. Therefore, we propose a technique that (1) does not require the user to go through the menu structure and (2) does not *hinder* the user when using another method rather than the keyboard shortcut.

Our proposed *Keycue* technique is based on the premise that users will generally know that a keyboard shortcut is invoked using a modifier key such as ‘Ctrl’ or ‘Alt’, but not know the exact key combination for a certain command. *Keycue* shows a list of *all* available keyboard shortcuts when a modifier key is pressed and held down for a number of seconds (which we consider to be indicative of the user wanting to use a keyboard shortcut, but not knowing the exact key combination).

We consider this approach to have several advantages. First, it does not remove or modify any of the other functionality of the user interface. Secondly, as it shows all keyboard shortcuts in one overview, incidental learning of nontarget keyboard shortcuts can take place. This is opposed to the scenario where keyboard shortcuts are only visible in their relevant locations in the menu structure.

### 5.1. Method

We investigated the effects of the *Keycue* technique in a graphical editor. Using a novel/unfamiliar program allowed for studying the effect of Keycue on ‘familiar’ shortcuts (that are also available in programs such as Microsoft Word) as well as novel ones, exclusive to the graphical editor. The frequency of use of various methods was studied for several commands that are also present in Microsoft Word as well as some novel commands. In total, 12 commands were studied: open, new, save, copy, paste, circle, rectangle, polygon, group, ungroup, order and align. Participants were to complete several assignments in the graphical editor, including drawing objects, copying and pasting objects and changing the order (front/back) of objects. In these assignments, if performed error-free, all 12 commands under investigation would be issued at least once (the number in brackets is the number of times the command was used in total):

(i) opening a file (2)
(ii) creating a new file (2)
(iii) saving a file (2)
(iv) copying an object (4)
(v) pasting an object (5)
(vi) drawing a circle (2)

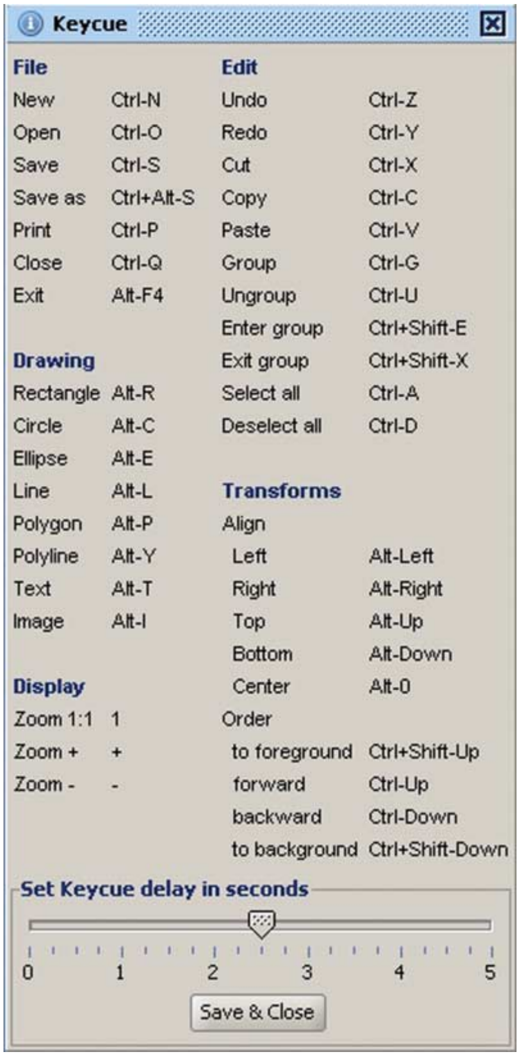


**Figure 2.** The Keycue window, available for the experimental group in Experiment 3.

(vii) drawing a rectangle (4)
(viii) drawing a polygon (1)
(ix) grouping objects (2)
(x) ungrouping objects (2)
(xi) changing the order of objects, e.g. moving an object to the background of the scene (5)
(xii) aligning objects (3)

### 5.1.1. *Software*

An open source graphical editor called GLIPS Graffiti Editor (GLIPS) was used.[2] GLIPS is a basic vector-based graphical editor which allows the user to make relatively simple images. Features include shape tools (for example, rectangle, circle), path tools (for example, Bezier curves), basic text support, and image import and export. Several modifications were made, including adding some buttons to the toolbar, adding or modifying keyboard shortcuts for several commands and fixing minor bugs. Also, we added a *Keycue* function. When pressing and holding down the 'Ctrl' or 'Alt' button for a number of seconds, a small window with a list of all the available keyboard shortcuts would pop up (see Fig. 2). In the Keycue window, the various commands and their respective shortcuts are grouped similar to their grouping in the menu structure of the program. At the bottom of the Keycue window, the delay (the number of seconds the 'Ctrl' or 'Alt' button should be pressed down before the Keycue window pops up) could be modified by the user, ranging from 0 to 5 s. By default, the delay was set to 2 s, as pilot testing revealed that both (much) shorter and longer delays might hinder the user. The Keycue window could be closed using the Escape button on the keyboard or by pressing the 'x' button in the Keycue window. Finally, the Keycue function could also be disabled and enabled via the menu. Two versions of GLIPS were created, one with and one without the Keycue function. It should be noted that all the keyboard shortcuts were also visible in the regular drop down menus at the top of the interface in both versions. Logging software (identical to the software used in Experiment 1) was used to record all actions performed by the participants in an unobtrusive manner.

[2]Version 1.4, http://sourceforge.net/projects/glipssvgeditor/, last accessed January 4, 2012.

### 5.1.2. *Design and procedure*

To study the effects of the Keycue function, participants were divided into two groups, half of the participants used a version of GLIPS, including the Keycue function (the experimental group) and the other half used a version without this function (the control group).

All participants were given a short instruction about the use of GLIPS, including some practice assignments, to get familiarized with the basics of the program. For the experimental group, the Keycue function was also shortly explained in the instructions, including a small practice assignment on how to use the Keycue function. To ensure that participants in the experimental group did not think they were not allowed to use the Keycue function unless specifically told so in the assignments, they were reminded at the end of the instructions that they were free to use the Keycue function at any time during the assignments.

For further details on the design and procedure of Experiment 3, refer to Section 4.1.2.

## 5.2. Results and discussion

The group that used GLIPS with Keycue used the keyboard shortcut for 58.0% ($SD = 21.9\%$) of the commands and the group that used GLIPS without Keycue used the keyboard shortcut for 11.8% ($SD = 20.2\%$) of the commands. This difference is significant (Mann–Whitney $U$ test, $P < 0.001$). An overview per command can be seen in Table 3. We note that the two groups did not differ in their keyboard shortcut use in the assignments in Experiment 2 (Mann–Whitney $U$ test,

**Table 3.** Percentages the keyboard shortcut was used to issue a command by the participants in the assignment in GLIPS in Experiment 2.

| | % keyboard shortcut use ($N$) | |
|---|---|---|
| Command | With Keycue | Without Keycue |
| Open | 25.0 (40) | 0.0 (40) |
| New | 32.5 (40) | 0.0 (40) |
| Save | 28.9 (36) | 15.8 (36) |
| Copy | 89.2 (78) | 55.0 (80) |
| Paste | 90.3 (97) | 53.0 (100) |
| Circle | 66.1 (40) | 2.8 (40) |
| Rectangle | 62.5 (80) | 5.8 (79) |
| Polygon | 50.0 (20) | 0.0 (20) |
| Group | 55.3 (33) | 6.7 (24) |
| Ungroup | 52.9 (28) | 0.0 (21) |
| Order | 63.0 (99) | 1.1 (94) |
| Align | 80.0 (58) | 1.7 (59) |
| Mean | 58.0 | 11.8 |

$P > 0.1$). Evidently, the presence of the Keycue function has a significant effect on the use of keyboard shortcuts.

There were five commands that were used in both the assignments in Microsoft Word and the assignments in GLIPS: open, new, save, copy and paste. The keyboard shortcuts for these commands were the same in both programs. This allows for an analysis of the effect of Keycue on the use of keyboard shortcuts for familiar commands (rather than new/unfamiliar ones that were only introduced in the assignments in GLIPS). The participants in the group that used GLIPS with Keycue used more keyboard shortcuts for familiar commands in GLIPS than in Microsoft Word ($t(4) = -6.78$, $P < 0.01$), but we find no significant difference between the use of shortcuts for familiar command in GLIPS and Microsoft Word for the participants without Keycue. In conclusion, the participants with Keycue not only used more keyboard shortcuts than the participants without Keycue for the new and unfamiliar commands in GLIPS, but also for familiar commands that are present in both Microsoft Word and GLIPS.

We note that although it is generally agreed upon that, keyboard shortcuts are the fastest method for issuing a command, a tool like Keycue could initially slow users down somewhat (as they have to wait for the window to pop up).[3] Therefore, we recommend future work investigating the effect of Keycue over longer periods of time and/or in more naturalist settings.

## 6. CONCLUSION

The results of Experiment 3 show that with Keycue, which is a tool that assists users learning keyboard shortcuts, the frequency of use of keyboard shortcuts can be increased, both known/familiar keyboard shortcuts as well as novel shortcuts.

[3]We thank an anonymous reviewer for bringing this to our attention.

## 7. LIMITATIONS OF STUDY

In this section, we discuss several potential limitations of the current study, including that the experiments took place in a lab setting, the limited length of Experiment 1 and the fact that the participants in the experiments were all university students or employees.

First, we note that all experiments reported in this paper took place in a lab setting. For Experiment 1, this means that the participants were using an unfamiliar computer, possibly with a different layout than the system they use normally. Partly, we addressed this potential problem by configuring the toolbars such that all commands under investigation were visible on the toolbar by default. This design choice implied that if a participant was used to using the toolbar icon for the command under investigation they would not be hindered or confused by the fact that the toolbar icon was not present. On the other hand, for a participant who was not used to having the toolbar icon visible for a specific command, this might have lowered his/her frequency of use of other methods, such as the keyboard shortcut. However, we consider the latter situation to be less likely and less severe than the former. The toolbar is quite crowded, and we doubt participants would specifically notice an icon that is normally not there. On the other hand, the absence of an icon that usually is there would be very disruptive for the user, and with our design choice this never happens. Nevertheless, a (longitudinal) log study on actual keyboard shortcut use in real life could shed more light on how people employ various methods under more everyday conditions. We are not aware of any studies that have done this, but we think that this could be a useful future contribution.

Another limitation of the lab setting could be identified in Experiment 3. In Experiment 3, we demonstrated how the Keycue tool increased the use of keyboard shortcuts. However, we cannot rule out the possibility that participants were primed to use keyboard shortcuts by the instructions of the experiment. It would be interesting to see how a tool like Keycue influences keyboard shortcut use in a more natural setting. Nevertheless, our experiment provides a proof of concept that a tool like Keycue can increase the use of keyboard shortcuts.

Secondly, we recognize that the infrequent use of keyboard shortcuts in Experiment 1 could be explained by the limited length of the study. Possibly, the participants would have used keyboard shortcuts more often if they had to invoke certain commands more often. Although we cannot rule out this possibility, there was at least no evidence in our data that the frequency of invocation of certain commands influenced the frequency of use of keyboard shortcuts, though we acknowledge that the number of command repetitions in our study was relatively small, ranging between one and four in Experiment 1.

Finally, the participants in all experiments were all students or employees of a technical university, and therefore probably a population of more advanced/expert users. The results of Experiment 1 (the under-utilization of keyboard shortcuts) are most likely only exasperated for a less-advanced user population, if there is an effect of user population on shortcut use at all. For instance, Peres *et al.* (2005) found no relation between typing abilities, familiarity with computers and the use of keyboard shortcuts. However, in contrast to Experiment 1, the results of Experiment 3 (the increased use of keyboard shortcuts by the experimental group) might be less pronounced for a less-advanced user population. Therefore, future work could focus on the effects of a tool like Keycue for a less-advanced or beginner-user population.

## 8. GENERAL DISCUSSION

The findings in Experiment 1 confirmed that people infrequently use keyboard shortcuts. We also found that this cannot be fully explained by a lack of knowledge of keyboard shortcuts. This motivated further investigation as to why people infrequently use keyboard shortcuts. We explored several factors in Experiments 2 and 3. In this section, we argue that the results found can be explained using the notion of 'satisficing'.

We will first introduce the theoretical background of satisficing and discuss how we can apply this notion to explain the infrequent use of keyboard shortcuts. Next, we consider an alternative explanation of our results, i.e. multifactor optimization, and argue that this explanation seems to have less psychological plausibility given known limitations on cognitive processing resources. Although our satisficing explanation is psychologically plausible, we do recognize that in its current form it is incomplete, as it can only explain why people accept a certain (possibly sub-optimal) method, but not why this method was the first candidate method. Therefore, we present possible hypotheses that can complement our satisficing explanation. We close with a discussion of the implications of our results.

### 8.1. Satisficing can explain the infrequent use of keyboard shortcuts

In traditional economic theory, humans are assumed to be completely rational and maximize utility for all decisions and actions. This view was contested by Simon (1955, 1956). He argued that people are only *boundedly rational*. Bounded rationality means that people are limited in their rationality by environmental factors, such as time or available information, and cognitive limitations, such as the inability to foresee all possible outcomes and their respective values. A behavioral strategy given this notion of bounded rationality is *satisficing*. When satisficing, people are content with an option or outcome that satisfies their goals, even though it might not maximize efficiency, effectiveness or utility. More informally, one could say that they accept what is 'good enough' or sufficient, not necessarily the best. Satisficing acts as a 'stopping rule'; an individual will set a certain aspiration level and accept the first option that meets this aspiration level (Gigerenzer and Todd, 1999). It is important to note that satisficing is not optimizing with 'cost of obtaining information' taken into account:

> [. . .] contrary to this 'cost-minimising' misinterpretation, Simon's concept of bounded rationality refers primarily to the matter of computational capacity and not to additional 'costs'. Once it is recognised that 'bounded rationality' is essentially about limited computational capacity relative to a complex or extensive decision environment, rather than primarily the scarcity or cost of information, then its indissoluble link with the twin concept of satisficing is evident. (Hodgson, 1997, pp. 670–671)

We also stress that satisficing is not the same as 'optimization under constraints', a notion also strongly rejected by Herbert Simon himself (Gigerenzer, 2004):

> What is lost is psychological plausibility, because such an ideal of optimization invokes new kinds of omniscience, being able to foresee what additional information further search would bring, what it would cost, and what opportunities one would forgo during that search. Thus, retaining the ideal of optimization can make models of optimization under constraints more demanding than models of full rationality, both mathematically and psychologically [. . .] (Todd and Gigerenzer, 2003, p. 146)

Satisficing seems to be a general form of nonoptimal human behavior that need not to be confined to the domain of economic behavior. For example, it has been proposed that people may also show satisficing behavior in finding their way in the (built) environment (Arthur and Passini, 1992) and when using complex technology (Westendorp, 2002). We propose that satisficing behavior also provides a good explanation of why users infrequently use keyboard shortcuts. In the context of command invocation, we propose that the aspiration level of the user is often just to invoke the command, but not necessarily to *maximize* the efficiency of this action. In other words, as long as a method invokes the desired command, it is considered 'good enough'. We note that under certain specific circumstances the user's aspiration level could also include some notion of efficiency or other self-imposed constraints, such as when the user has to invoke a command often. In this case, the user's view of what is 'good enough' could include the efficiency of the method or, for example, the desire to not have to move the mouse too much. This could explain the finding from Experiment 1 that some commands are issued using the keyboard shortcut quite commonly, while for other commands the keyboard shortcut is hardly ever used: the commands for which the keyboard shortcut is used quite commonly are possibly the commands that are used most often in everyday use (such as cut, copy, paste and find).

Satisficing provides a good explanation of why people infrequently use the fastest method, or at least the method they indicate they think is fastest for them. The results of Experiment 1 show that people infrequently use keyboard shortcuts, and that this cannot be fully explained by a lack of knowledge of keyboard shortcuts. As this does not rule out the possibility that people do not know the keyboard shortcut is the fastest method, participants in Experiment 2 were asked what they thought was the fastest method for them for several commands. This revealed that the participants indeed do not always think the keyboard shortcut is the fastest method (10, 65 and 40% of participants indicated another method than the keyboard shortcut was fastest for them for copying, opening and bolding, respectively). Nevertheless, participants did not always use the methods they indicated as being fastest for them, even when under time pressure (13, 60 and 21% of participants used another method than the one they indicated was fastest for them for copying, opening and bolding, respectively). One of the most striking examples of this is that 38% of the participants use the menu for opening a document, even though they indicate that either the toolbar icon or the keyboard shortcut is fastest for them. This result can be explained by satisficing behavior: the goal of the user is to invoke the command (such as 'open a file'), but *maximizing efficiency* is not a goal. The higher efficiency of certain methods over others is not important enough; in other words, a certain (less efficient) method is considered good enough.

### 8.2. Could multi-factor optimization be an alternative explanation?

That users do not optimize one value, viz., speed, by using keyboard shortcuts does not by itself show that they are not optimizing. After all, users may find many factors important and in trying to optimize all of them some trade-offs may need to be made. For example, some keyboard shortcuts might be more error-prone, or users might trust them less. If a user considers factors such as the aforementioned important, then using a different method than a keyboard shortcut may be regarded as being better, albeit it slower. From a multi-factor optimization perspective, our results could thus be explained, for example, as the outcome of the maximization of a (possibly weighted) combination of factors.

Although we cannot rule out this in principle possibility, it seems implausible both on theoretical and empirical grounds that users optimize many different factors when selecting their methods of computer use. Multi-factor optimizing is a potentially difficult mental process (Payne *et al.*, 1993; Todd and Gigerenzer, 2003). One needs to weigh several factors in terms of relative importance. This weighing not only seems to presuppose some means of determining the value of each factor, but also a means of knowing how to weight each factor, and finally a computation of the overall value for each combination of factors. To illustrate, consider the simplified scenario where a person might consider only two factors: speed and the possibility of making a mistake (e.g. due to accidentally pressing the wrong button). To compare several methods on these two factors, it seems that one would first have to know the speed of these various methods. As was shown in Experiment 2, users do not always have an accurate view of which method is the fastest. Users would also have to know a probability value for a mistake to occur; for example, what is $P$ (mistake) for the keyboard shortcut and does this differ for various keyboard shortcuts, for example, depending on how easy they are to reach with one hand? Also, the severity of the consequences of the mistake needs to be taken into account; failing to save while you think you have saved is more problematic than failing to copy a piece of text. Then, these individual factors need to be converted into one value for each method. Is the probability of an error more important than speed and how does one quantify this? Even in this oversimplified model, with only two factors, optimizing seems a formidable task. Given what we know about cognitive task demands (Payne *et al.*, 1993), it seems implausible that users perform a multifactor optimization computation whenever they opt for a particular method for performing a function on a computer.

### 8.3. Which factors determine the first candidate method encountered?

While we believe that satisficing provides a plausible explanation for the infrequent use of keyboard shortcuts, we recognize that satisficing does not explain why a certain method comes to mind in the first place or which is the first method a user encounters. The notion of satisficing can only explain why people *accept* the first encountered method that satisfies their goals. In that sense, our explanation is incomplete. In this section, we provide several suggestions as to why certain methods come to the attention of the user first. We note that many of these explanations rely on so-called 'rules of thumb' or habit.

Habits can explain why a certain method (in this case, the method that the user frequently uses) comes to mind first. Habits are a way of being efficient; when relying on habits one does not need to think about what to do, thus saving time and effort. According to Verplanken *et al.* (2003, p. 1317) '[. . .] habits are efficient in the sense that they free mental capacity to do other things at the same time. The efficiency of habits appears in particular under conditions of heavy load, such as exhaustion, time pressure, distraction, or information overload'. Such an entrenched cognitive efficiency may explain why people do not use more keyboard shortcuts when under time pressure. After all, in that case we can expect participants just do what they always do regardless of the condition that they find themselves in Ouellette and Wood (1998).

Another possible explanation of why a certain method, and the toolbar icon in particular, is encountered first is that people tend to use recognition rather than recall. More specifically, toolbar icons are (usually) visible on the screen, and relatively consistent between applications, whereas keyboard shortcuts tend to be 'hidden' within menus, and people have to rely on recalling these shortcuts. As it is well known that recognition is typically easier than recall (e.g. Anderson and Bower, 1972), people are therefore more likely to use the toolbar icon which they can recognize rather than the keyboard shortcut they would have to recall. Another memory-based explanation of why the keyboard shortcut does not easily come to mind is that they might be encoded as declarative knowledge, but not as (well-practised) procedural knowledge (e.g. Anderson, 1996) and therefore do not come to mind readily.

Finally, a certain method might simply come to mind because it is prompted by the context, as shown in Experiment 3. The results of Experiment 3 show that a tool like Keycue greatly increases the use of keyboard shortcuts for both novel and known commands. Keycue makes it more likely that the most efficient method, the keyboard shortcut, is the first option a user encounters. It was indeed found that participants who used the version of GLIPS with the Keycue function used the keyboard shortcut significantly more often than the participants who used the version of GLIPS without the Keycue function. It would be interesting to see whether making another method, like the toolbar icon or the menu, more ‘prominent’ (such that it is the first option a user encounters) increases the use of this particular method. For example, if making the toolbar icons more prominent increases the use of toolbar icons and making the menu more prominent increases the use of the menu, this implies that users have no inherent preference for any method; whichever they encounter first is *good enough* and is subsequently accepted. This would provide stronger evidence of satisficing behavior. Such a lack of an inherent preference for any method also explains why Keycue increases the use of keyboard shortcuts for familiar commands, as found in Experiment 3.

### 8.4. Implications and future work

In this section, we argued that satisficing behavior provides a plausible explanation for the infrequent use of keyboard shortcuts. This raises two questions: (i) is it problematic that users satisfice and therefore infrequently use keyboard shortcuts and, if so, (ii) how can users be encouraged to use keyboard shortcuts more often? In response to the first question, one should keep in mind that nonoptimal behavior is not a bad thing per se. Satisficing is a good behavioral strategy in the sense that it is a strategy which requires little (mental) effort. In the context of complex technology such as computers, such a strategy facilitates automatic, unconscious behavior and a smooth ‘workflow’. Concerning the second question, the results of Experiment 3 suggest that providing a tool like Keycue can greatly increase the use of keyboard shortcuts. In the specific case of keyboard shortcuts, it has been suggested users should participate in training programs (Lane *et al.*, 2005), but this is a time and resource intensive method. This (costly) process of trying to teach users a new behavior when they are already experienced with a certain interface could be avoided by providing a tool like Keycue, so that users will start using them by themselves. We also note that some modern keyboards have keyboard shortcuts printed on the keycaps. Future work could examine whether these keyboards increase the use of keyboard shortcuts. We recommend future studies that investigate whether the positive effects of Keycue on keyboard shortcut use can be replicated in more naturalist settings and whether the effects last over longer time intervals. Finally, we believe that it would be interesting to explore whether indicators of satisficing behavior can be identified in other areas of interacting with computers as well.

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