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► To cite this version:

Gilles Bailly, Ignacio Avellino, Emeline Brulé, Sylvain Malacria. The Role of Social Interactions in the Interaction Discovery of Keyboard Shortcuts. IHM'25 - 36e Conférence Internationale Francophone sur l'Interaction Humain-Machine, AFIHM; Université de Toulouse; ENAC, Nov 2025, Toulouse, France. <10.1145/3765712.3765714>. <hal-05294608>

HAL Id: hal-05294608

<https://hal.science/hal-05294608v1>

Submitted on 2 Oct 2025

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The Role of Social Interactions in the Interaction Discovery of Keyboard Shortcuts

Le rôle de l'interaction sociale dans la découverte des raccourcis clavier

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Abstract

We investigate how the keyboard shortcuts method is discovered, a prerequisite for adopting their use. We designed and distributed a large-scale retrospective survey (N=853) focused on capturing narratives of first-time use of keyboard shortcuts. We find that (1) respondents largely report a social interaction as the event leading to the discovery, with only few reporting the use of computer aids such as tooltips; (2) most respondents discover keyboard shortcuts in elementary or middle school (6–14 years old), although this depends on the local educational policy; (3) the discovery generally occurs with a teacher, a classmate or family member while doing schoolwork; and, (4) respondents often report a strong emotional reaction to this discovery.

Résumé

Nous étudions comment la méthode des raccourcis clavier est découverte, une condition nécessaire pour leur adoption. Nous avons réalisé une enquête rétrospective à grande échelle (N=853) visant à recueillir les récits de la première utilisation des raccourcis clavier. (1) Les personnes interrogées déclarent souvent qu'une interaction sociale est à l'origine de la découverte, et peu d'entre elles déclarent avoir utilisé des aides informatiques telles que des infobulles; (2) les personnes interrogées découvrent les raccourcis clavier à l'école primaire ou au collège (entre 6 et 14 ans), bien que cela dépende de la politique éducative locale; (3) la découverte se fait généralement avec un enseignant, un camarade de classe ou un membre de la famille pendant les devoirs à la maison; et (4) les personnes interrogées font souvent état d'une forte réaction émotionnelle à la suite de cette découverte.

CCS Concepts

• **Human-centered computing** → *Keyboards*; **Interaction techniques**.

Keywords

Keyboard shortcuts, Discoverability, survey

Mots clés

Raccourcis clavier, découverte, questionnaire

Reference Format:

Gilles Bailly, Ignacio Avellino, Émeline Brulé, and Sylvain Malacria. 2025. The Role of Social Interactions in the Interaction Discovery of Keyboard Shortcuts. In *IHM '25: Articles Scientifiques de la 36^e conférence Francophone sur l'Interaction Humain-Machine, Novembre 4–7, 2025, Toulouse, France*. ACM, New York, NY, USA, 15 pages. <https://doi.org/10.1145/3765712.3765714>

1 Introduction

Keyboard shortcuts are a commonly available interaction method in GUIs, which enable users to trigger a command or a series of commands using one or a combination of keys [5], such as ctrl + C for copying text. This method has been demonstrated, both theoretically [12] and empirically [29, 46, 53, 63], to be faster to execute than the pointer-based alternatives such as menus or toolbars. Keyboard shortcuts are such a valuable resource for expert users [5, 29, 40, 54] that HCI practitioners have long recommended to support their use [61]. Many blog posts from end-users further demonstrate the benefits of keyboard shortcuts to interact with operating system (e.g., Windows¹, applications (e.g., Photoshop², Office³ or Chatbots (e.g., ChatGPT⁴) and increase productivity or reduce the strain caused by repetitive motions [36]. Moreover, they are sometimes even necessary to activate commands that do not have a visible menu item equivalent (e.g., commenting a paragraph in Overleaf). Finally, some keyboard shortcuts are so ubiquitous across applications (e.g., copy (Ctrl+C) and paste (Ctrl+V)) that they can be considered a core skill in computer use, which Covello and Lei [18] describe as instrumental competence, i.e. the technical ability to interact with a digital system. For instance, their use is one component of measuring digital adaptability [74], because they

¹The most useful Windows hotkeys: https://www.reddit.com/r/Windows10/comments/127o007/the_most_useful_windows_hotkeys/

²41 Essential Photoshop keyboard shortcuts to speed up your workflow: <https://thattogspot.com/essential-photoshop-keyboard-shortcuts-to-speed-up-your-workflow/>

³The ultimate keyboard shortcut guide for Word, PowerPoint and Excel: <https://www.templafy.com/the-ultimate-keyboard-shortcut-guide-for-word-powerpoint-and-excel/section-7>

⁴How To Use ChatGPT Shortcuts To Enhance Your Productivity: <https://autogpt.net/how-to-use-chatgpt-shortcuts-to-enhance-your-productivity/>

require a deliberate effort to be learned, usually with the longer-term goal to improve performance or ease-of-use. In other words, using keyboard shortcuts is associated with, and may nurture, a greater ability to learn new systems or features.

Yet, in spite of their benefits, keyboard shortcuts remain underused [9, 43, 67], either due to difficulties memorizing key combinations [26, 46, 77] or lack of awareness that keyboard shortcuts exist for certain commands [29, 40]. It may even be that **some users are not even aware that the keyboard shortcut method exists** [9]. However, we know surprisingly little about how *interaction discovery* of keyboard shortcuts happens, i.e. the situation where users discover the existence of an interaction **method** to interact with an interactive system [51]. It follows that we also do not know how to facilitate its discovery to later foster the learning and adoption of keyboard shortcuts. In this article, we investigate the interaction discovery of keyboard shortcuts, focusing on the following research questions:

- RQ1: *Which events lead to the interaction discovery of keyboard shortcuts?* Keyboard shortcuts are not restricted to a task or a domain. Do some events – activities or technical scenarios (software or systems) – favor the interaction discovery of this method?
- RQ2: *Which aids contribute to the interaction discovery of keyboard shortcuts and how?* Previous research suggests computer aids (e.g., menu labels [27]) or external resources (e.g., user manuals) have limited impact on learning new keyboard shortcuts, but how do they impact their interaction discovery? Are existing computer aids sufficient to discover the interaction method and if yes, why do they not motivate users to learn or use them more?

To do so, we designed a *retrospective survey* with a large panel of participants ($N = 853$). Such surveys enable to collect a broad range of retrospective narratives about the interaction discovery of a given interaction method [69, 70], which is difficult to observe in the field, given we do not know when or where the interaction discovery happens. Our contribution is threefold:

- (1) a better understanding of the interaction discovery, of keyboard shortcuts specifically, but also more generally on the discovery of interaction methods; Our results reveal the prominent role of social interaction and educational policy as well as the strong emotional reactions associated with the discovery. They also question the differences between interaction and feature discovery.
- (2) a better understanding of social interactions by highlighting the specificity of our use case on Over-The-Shoulder Learning (OTSL), educational policy, and magic phenomena.
- (3) several design opportunities for the adoption of keyboard shortcuts based on our empirical findings.

2 Background and Related Work

We first discuss keyboard shortcuts as a digital skill and then disambiguate the concept interaction discovery from related concepts to conclude what can be presumed about the discovery of this method.

2.1 Keyboard Shortcuts as a Digital Skill

Keyboard shortcuts often involve the use of modifier keys (e.g., control, command) in combination with one or several characters (the *hotkeys*), held all at once or pressed consecutively. While modifier keys may slightly differ, typically between macOS (that predominantly relies on the command/CMD key) and other OS (that predominantly rely on the control/Ctrl key), they usually rely on the same *hotkeys*. Several computer aids are available to favor keyboard shortcut usage: cues are generally displayed next to a command in menus or included in a tooltip when a mouse pointer hovers a toolbar button [5]; keyboard shortcuts can also be listed in instruction manuals, documentation or external resources (blogs, online tutorials). It is also common that "Tip of the day" presents keyboard shortcuts.

Keyboard shortcuts are widely available across applications such as everyday applications (e.g., Microsoft Word), expert applications (e.g., AutoCad) or chatbots (e.g., ChatGPT⁵) and thus are a core digital skill [18]. It remains that this efficient method is underused [5, 9, 43, 67] which motivated multiple theoretical [4, 13, 21], empirical [43, 63, 67] and design [6, 26, 29, 40, 46, 53, 77] studies.

The closest work in terms of goals and methodology was conducted by Peres and her colleagues [43, 67, 68, 72] who administered questionnaires to explore why people use, or do not use, keyboard shortcuts. They confirmed keyboard shortcuts are efficient, perceived as useful, but seldom used. Interestingly, they also suggest that working with people using keyboard shortcuts is an important factor of shortcuts usage because they know people using a lot of shortcuts and can watch them using shortcuts (sometimes when working on the same computer). Regardless, these studies were conducted two decades ago and focus on keyboard shortcut usage and/or learning, but not on their *interaction* discovery.

2.2 Interaction Discovery

Mackamul et al. [51] proposed a classification of "discoveries" given the lack of consistency in the terminology and definition⁶. They distinguish discoveries in term of the type of knowledge and actions necessary to fully exploit interactive systems.

- *Feature discovery*, the situation where users discover the existence of a new command (or feature) to achieve a task [49]. For instance, they discover the command "Duplicate" which combines "Copy" and "Paste", they discover the keyboard shortcut associated to "Copy" is CMD C. Regarding voice input, they discover which words are interpreted by the system [87].
- *Interaction discovery*, the situation where users discover the existence of a method [49]. For instance, that combining a modifier and a letter (keyboard shortcuts) or talking (voice input) triggers a command.
- *System discovery*, the situation where the users discover a whole system and its interactivity. It has been typically investigated in the context of public displays where users discover that it is more than a simple passive screen.

⁵How To Use ChatGPT Shortcuts To Enhance Your Productivity: <https://autogpt.net/how-to-use-chatgpt-shortcuts-to-enhance-your-productivity/>

⁶Different terms are used interchangeably in the literature for very similar notions: feature discovery [48, 52], tool discovery [22, 59, 60, 65], command discovery [73], feature awareness [25, 31] or vocabulary extension [15, 53].

These three types of discoveries have in common that users learn new possible actions and are strongly anchored in the software learning literature [15, 31, 61]. In the past, systems were shipped with user manuals to provide an overview of systems' capabilities but in practice, users rarely use these manuals [11]. Manufacturers now often expect users to **discover** system, interaction and features on their own, either because they already have basic digital skills to discover these services, watching system presentation keynotes, or actively searching for information (for instance through an online search) [57]. While indeed users are aware of the basic ways to interact with systems, for instance tapping on a touchscreen or using a mouse cursor to activate widgets, many may ignore that certain interaction and features are available. Previous work thus aim at assisting users in figuring out what actions are possible and where and how to perform them [61, 62].

Feature discovery. Previous work almost exclusively focuses on feature discovery, typically which commands are available (e.g. [55, 56]) and what are their corresponding keyboard shortcuts (e.g. [26, 29, 41, 53]). It revealed that users often discover features via informal help given between users [24, 25, 35, 38, 82]. The most salient example is "over-the-shoulder learning" (OTSL) [7, 8, 79] that typically takes place informally, often in workplaces, where co-workers observe and pick up skills and techniques by watching others, rather than through formal training sessions. However, previous work usually assumes that the user is already familiar with the interaction methods and devices that are used to operate the system in order to access the discovered features (typically, the existence of the keyboard shortcuts method or the mouse pointer to browse a menu bar).

Interaction discovery. Interaction discovery received less attention than feature discovery [50, 70, 85], while being an important aspect of software learnability and has its own specificity which is that it typically happens once for a given method, making it harder to observe. The problem of interaction discovery is particularly salient for emerging technologies. For instance, users might know how to interact in Augmented Reality using mid-air gestures, but ignore they can also interact by performing touch gestures on the frame of interactive glasses. This might be why *interaction* discovery is almost exclusively considered when novel technologies are introduced on the market (e.g. public displays [85]) or when researchers are proposing a novel interaction method they presume difficult to discover [2, 28, 34, 85]. However, the problem of interaction discovery is also prominent with widely adopted devices. For instance, many iPhone users are not aware of the 3D touch [37], or, regarding the focus on this article, many users ignore the existence of keyboard shortcuts as interaction method on PCs [31]. Ignoring such methods can impact productivity [5] and users' ability to exploit a system to its full potential. To our knowledge, only two studies specifically investigated the contexts in which interaction discovery happens. The first is a survey on the *interaction discovery*, awareness and adoption of Swidgets - widgets revealed by swiping on smartphones [70]. The second is a project investigating the interaction discovery of gestures on public displays [85]. Interestingly, these projects do not emphasize the role of Over-the-shoulder-learning, contrasting with how *features* are discovered and prompting a reevaluation of the role that social

exchanges play in the discovery of *interactions*. More precisely, the former indicates that only 5% of the participants reported having discovered this method through social interaction, i.e., by receiving a demonstration or witnessing somebody else doing it. The latter suggests that users discover the gestures inadvertently or because they are contained in interwoven sequences [85]. Studies focused on how professionals discover new tools available in software similarly find that despite the belief peer learning is a main driver of discovery, it is rarely the case [59, 60].

System discovery. In the era of computing devices ubiquity, people are likely to know at the very young age that smartphones, tablets or PCs are interactive. However, it not the case for all devices. For instance, passers-by do not not necessary knows or expect public displays to be interactive [58]. Müller et al. [58] thus investigated the influence of different factors (e.g. feedback of passer-by's incidental movements) to communicate the interactivity of a display. Another example is glasses that users do not expect to be interactive, while recent models provide augmented reality capabilities [80]. However, in our context, we assume that users already know to use a keyboard to interact with a PC.

To sum up, keyboard shortcuts are commonly available and a core digital skill. While interaction discovery of keyboard is a prerequisite for the learning and/or adoption of keyboard shortcuts, it is surprising to observe that we know very little about the general context in which the interaction discovery of this method occurs (e.g., task, activity, software used, etc.) as well as the role of the different aids (computer and social) and external resources in the interaction discovery. In particular, previous studies have offered conflicting information regarding the role of social interaction in keyboard shortcuts discovery.

3 Study

The study aims at better understanding the interaction discovery of keyboard shortcuts.

3.1 Methodology

Inspired by previous studies on interaction discovery [69, 70], we developed an exploratory survey aimed to collect a wide range of **retrospective narratives and reflections** about the circumstances in which users discover the keyboard shortcuts method. One specificity of interaction discovery is to happen *once* in a lifetime for a given user and a given method. It results that laboratory studies, field studies or diary studies are not suitable, as we do not have prior information on when the phenomenon happens.

A risk of our retrospective survey methodology is that participants memory is incomplete or distorted. Thus, we took two precautions. First, we recruited a large panel of participants ($N = 853$). Second, we focused on University students because we thought they were more likely to have discovered keyboard shortcuts recently. Some recent industry research on keyboard shortcuts suggests 20%

of University students in Japan do not know **any** keyboard shortcuts⁷. This is consistent with our experiences as University professors where we observed that several students in our cohort discovered the keyboard shortcut method during exercises, suggested that university students were a relevant population to explore the interaction discovery of keyboard shortcuts. Finally, we did not present the study as focusing on keyboard shortcuts. A survey on keyboard shortcuts risks obscuring that some computer users do not use or do not know about keyboard shortcuts. Therefore we presented it as a study of “digital skills”.

3.2 Survey Design

The survey was implemented using the LimeSurvey⁸ platform. It was distributed between the 22nd of April 2021 and the 24th of May 2021. It covered all aspects of keyboard shortcut adoption and usage (see Appendix), but we focus here on two questions about the discovery of keyboard shortcuts:

- Do you know what keyboard shortcuts is? [Yes; No; I don't know] -> if the answer is No, an explanation of what keyboard shortcut is.
- Did you already used keyboard shortcuts? [Yes; No; I don't know] -> if the answer is No the survey ends.
- When did you first discover keyboard shortcuts, approximately? [I don't know; <1 month; between 1 month and 1 year; between one and two years; between two and five years; More than five years]
- Can you describe when and how you discovered keyboard shortcuts? Was there a particular event or trigger that led to this discovery? [Open field, paragraph]
- Did you start using keyboard shortcuts immediately after this event? [Yes; No; I don't know]

We phrased the open field, qualitative question with two main hypothesis: that respondents would remember a discrete event during which they discovered keyboard shortcuts, and by asking where this event happened, we may aid recall [45]. However, we did not have hypotheses about what would be the salient aspects of this experience.

The survey also contained demographic questions (gender, age, occupation and highest degree, or degree pursued and year of study - see Appendix for all questions) that can influence the interaction discovery of keyboard shortcuts [64]. We received ethics approval from four universities [anonymized for submission] in France, the United States and the United Kingdom. The survey was available in both languages, in which the researchers are fluent. Participants answered in the language of their choice. There are no significant concerns about the data, as the questions are not sensitive and minimal personal data was collected.

3.3 Participants

Participants were recruited through two channels: mailing lists from four universities and through snowballing on social media. A total of 1619 people anonymously participated in our survey, and 856

responses were actually complete. Participants were anonymous and did not receive compensation. Of all respondents, only three reported having never used a keyboard shortcut, and ten didn't know how they were called.

Participants took on average 283 seconds (median 204s, min 16s, max 2699s) to answer to the questions analyzed here. 649 respondents (76%) answered the open field question but with different levels of details (average 209, median 163).

The respondents included 609 students (71.4% of all respondents) and 244 respondents in the workforce (28.6% of all respondents). They were between 18 and 74 years old (mean 27.3, median 23, σ 10.9). 44.4% (379) identify as women, 50.4% (430) as men, 2.2% (19) as non-binary, and 0.8% (7) reported multiple gender identities; 2.2% of participants declined to describe their gender. Students' field of study was primarily Sciences (except computing) (39.6% of all respondents), Computing (24.7%), Engineering and manufacture (8.6%), while social sciences, humanities and the arts, general programs, health, education, and services were less represented (5.5% combined). This is due to those departments not having students' mailing lists, or declining access. Some students reported two majors.

For workers, main occupations included army employees (8.6% of all respondents), Plant and machine operator or assembler (3.3%), craft and related activities (2.8%), skilled agricultural, forestry or fishery worker (2.5%), Science or engineering professional (2%), Information and communications technology professional (2%), Service or sales worker (personal care, protective services, personal and restaurant service) (1.5%), ICT professionals (1.4%) and cleaner/labourers (1.3%), as well as health, legal, office, managerial. While doctoral degrees are over-represented (13.7% of respondents), our sample still includes 3% of respondents with a high school, primary school or non-academic degree and 4.8% of new high school graduates in their first year of post-secondary education. This is a non-random sample, limiting generalization as we primary focused on university students (see section 3.1) for this exploratory study.

3.4 Data Analysis

For closed questions we counted occurrences of responses. For open questions, we classified the situations encouraging the discovery. There was no specific theme we were expecting to find in the data, we thus followed an inductive approach divided into four phases:

- (1) A researcher went through the first hundred answers adding codes categorizing situations in which the discovery occurred (e.g., video games) and realized that the situations were much more varied than expected and required a more systematic and detailed descriptive approach.
- (2) The researchers then decided to use descriptive codes for different aspects of the anecdote following the 5W1H framework (What?, When?, Where?, Who?, Why?, How?). This framework is used in CSCW [32, 79] and HCI research [66].
- (3) In parallel, the second researcher used the same codebook on 50 answers. Given the descriptive nature of the codebook, consistency across coders was high. However, these discussions pointed to an aspect of discovery that was not covered by the 5W1H framework: the *immediate reaction*

⁷See <https://prtimes.jp/main/html/rd/p/000000040.000029909.html>, covered in English in <https://www.tomshardware.com/news/survey-finds-40-percent-of-university-students-in-japan-dont-know-shortcut-keys>

⁸<http://www.limesurvey.org/>

of the participants, which shed light on starting to use keyboard shortcuts and the emotional valence of interaction discovery.

(4) The first researcher then coded all 853 answers.

4 Results: Keyboard Shortcuts Interaction Discovery

689 respondents out 853 (81%) answered the question: “Can you describe when and how you discovered keyboard shortcuts? Few (40) answered not remembering a specific event (when/how) related to it, for example because it was a long time ago (11) or because they were too young (4). 18 of these respondents indicated that they have “always known/used” keyboard shortcuts and 7 other indicated that keyboard shortcuts are “natural”.

We now synthesize our results using the 7 categories (6 for 5W1H + 1 for perception of the discovery) as a framework. We also report descriptive statistics for a given code, and the percentage calculated as the number of considered narratives divided by the number of participants to our survey (853 = 856 – 3 participants who never used keyboard shortcuts). Figure 1 summarizes the proportion of the 853 respondents who provided information on the six components of the 5W1H framework and shared their perception of the discovery

4.1 What Technical Events Led to the Discovery of the Keyboard Shortcuts Method?

In this subsection, we describe the *technical* context surrounding the interaction discovery of keyboard shortcuts at different levels of granularity: command, software, activity, hardware. The results are summarized Figure 2. 346 respondents (40%) mentioned a specific **command** or its corresponding keyboard shortcut. More than half of them reported <Copy; Ctrl+C> (297) and <Paste; Ctrl+V> (299) (some reported both). Other keyboard shortcuts are much less frequent: <Cut; Ctrl+X> (43); <Undo; Ctrl+Z> (17); <Save; Ctrl+S> (11), <Terminate Application Task; Ctrl+Alt+Del> (7) or <Close Current Window; Alt+F4> (7). The most reported **software** type is a word processor (e.g., Microsoft Word) (133; 16%). Other office software were also reported (37), including Spreadsheets (e.g., Excel) (7); Presentation program (e.g., PowerPoint) (3); Web browsers (9), File systems (7), among others. The most common **activity** is word processing (133; 16%), while other reported activities include programming (8), gaming (5) or video editing (1). Beyond the activity itself, respondents often associates the interaction discovery to a new and/or intense task requiring high productivity such as writing a report or thesis (14).

Regarding **hardware**, 15 indicated that the discovery was concomitant with the use of their first computer. However, we did not find evidence suggesting that a system (e.g., Mac) impacts discovery in specific ways. Finally, technical problems can trigger the interaction discovery. A reported hardware problem (3) is the fact that the pointing device is broken or damaged. A typical software problem (3) is a frozen software with the mouse unresponsive. In short, finding workarounds to command execution leads to the unintended discovery of the keyboard shortcuts method.

In summary, our main findings are that the discovery is often associated to situations (1) involving the commands “Copy”

and “Paste”, (2) during new and/or intense activity (often involving a word processor), or, (3) when a technical problem occurred (e.g. mouse broken) requiring an alternative input method. They are well summarized by these two quotes: “P1025: [...] *When we had our first computer at home (Mac), [my father] showed me the abc of word processing, starting with the ‘apple C’ ‘apple V’*”, and “P1038: *I was taught the use of the shortcut for the windows task manager [<Terminate Application Task; Ctrl+Alt+Del>] to get out of a software that had frozen.*”

4.2 How Do Users Discover the Keyboard Shortcuts Method?

306 (36%) respondents specify *how* they learned about the existence of the keyboard shortcuts method. The results are summarized Figure 3: Respondents rarely report spontaneous discovery but highlight a range of social interactions leading to interaction discovery.

4.2.1 Individual Learning. Few respondents (54; 6%) reported having discovered the keyboard shortcuts method by themselves—i.e., without interacting with other persons. We identify two main classes of individual learning: active search and computer-assisted discovery. First, 25 respondents (3%) mentioned discovering the method as a consequence of **actively searching** to learn how to use the system/software and/or improve their performance. Typically, they do a dedicated search on the internet (13; 3%), watch a video tutorial (5; 1%) or visit a blog (1). They also use the Help menu of an application (1) or read the computer manual (4; 1%). One respondent mentioned having performed a systematic exploration of the keyboard device and discovered keyboard shortcuts.

The second class of individual learning is **computer-assisted discovery**, situations where the system “pushes” information to the users about keyboard shortcuts (29; 3%). Respondents mentioned traditional menus (14; 2%), *tooltips* (7; 1%) and *tips* (2; < 1%), i.e. the suggestions proposed by a software such as the tip of the day, or an office assistant (e.g. Clippy in Microsoft Word). Interestingly, five narratives (1%) mentioned discovering keyboard shortcuts as a result of Google Docs disabling mouse-based activation of copy and paste: “P1391: *I was using Google Drive [...] and I found that I could not use the normal method of copying/cutting/pasting in Google Docs/Sheets/Slides/etc. I got an error message that said I had to use the keyboard shortcuts, so I did. [...]*”⁹.

To sum up, our results show that users rarely learn the existence of the keyboard shortcut method by themselves (only 6% in our survey). Two participants shed light on possible explanations. P47 emphasized that keyboard shortcuts aids in menus did not retain her attention. More surprisingly, P821 emphasized the difficulty to interpret keyboard shortcuts textual description. “*I saw Ctrl+Z appear when you place the mouse over the [toolbar button], without clicking on it [tooltip]. I thought at first that you had to press Ctrl then Z, but it did not work! You had to keep pressing Ctrl while pressing Z!*”

⁹Until recently, browsers could not access the clipboard for security reasons, and thus when users selected the copy or paste menu items on Google Doc, the system showed a pop-up instructing the user to perform these commands through keyboard shortcuts, https://www.reddit.com/r/google/comments/tnnjb/good_guy_google_forcing_the_masses_to_use/

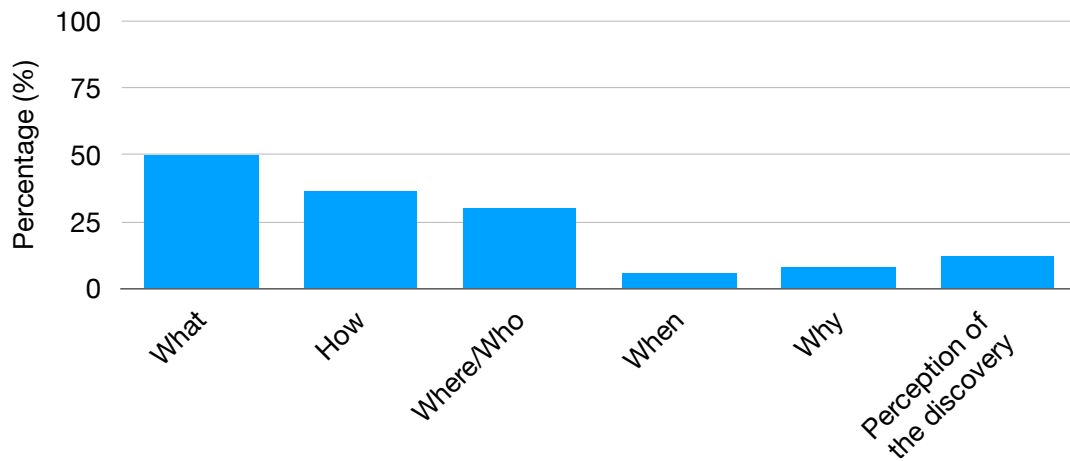


Figure 1: Proportion of respondents (N=853) who provided information on the six components of the 5W1H framework and shared their perception of the interaction discovery.

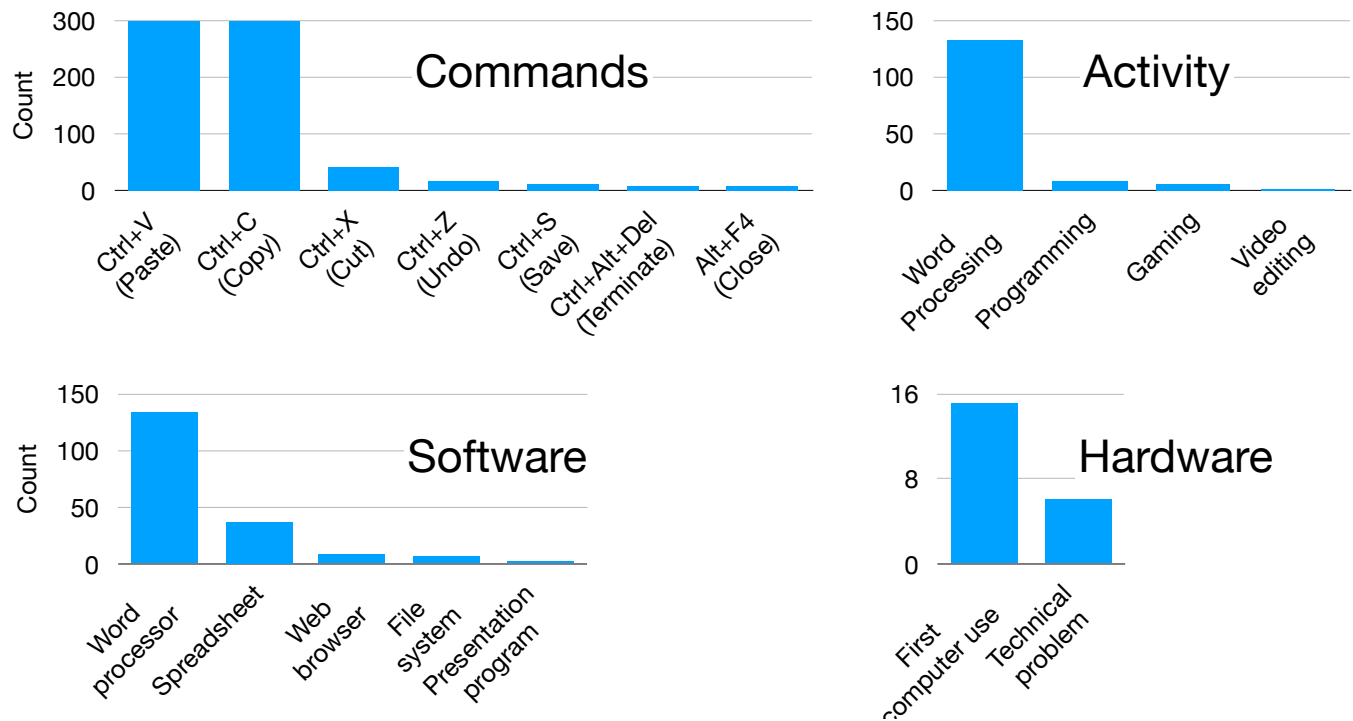


Figure 2: Technical context surrounding the interaction discovery of keyboard shortcuts at different levels of granularity: command, software, activity, hardware.

4.2.2 *Learning Through Social Interaction.* Of the 306 respondents describing the manner of discovery, 238 (28% of all respondents) mentioned social interaction, all corresponding to face-face interactions. We identify four scenarios:

- The help giver observes the learner over the shoulder and spontaneously/informally explains what keyboard shortcuts are and how to execute them (209; 24%), typically to save time and/or reduce the number of clicks.
- The help giver formally teaches about keyboard shortcuts, most commonly a teacher to a group during a class.
- The learner observes a user over the shoulder (28; 3%). The observation might be sufficient to understand the interaction but not always. If not, the learner is then active and interrupts

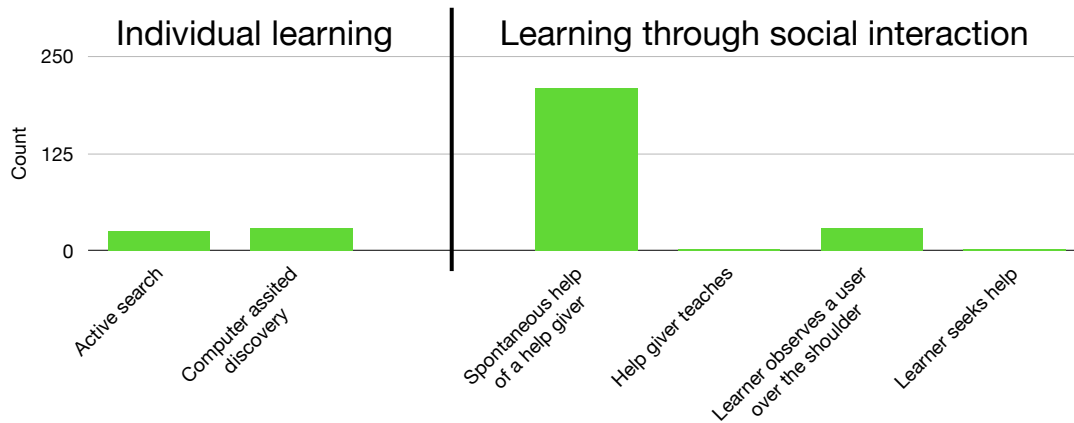


Figure 3: How do users discover the keyboard shortcut method? Respondents rarely report spontaneous discovery (individual learning) but highlight a range of social interactions leading to interaction discovery

verbally the user to ask for more details. One respondent reported that the origin of the discovery was oral rather than visual: “P335: *My father does his Ctrl+C Ctrl+V while pronouncing them*”.

- The learner experiences a situation on their own and decides to seek help to understand the situation (2; 1%). For instance, the learner finds a cheatsheet or a post-it containing shortcuts, or accidentally hits multiple keys concurrently triggering a command then ask someone what that meant. While the discovery could be described spontaneous, it only made sense to the learner after social interaction.

4.3 Where Do learning through Social Interactions Occur and With Whom?

We now detail together *where* these social interactions occur, and the learners and help givers profiles (*who*). We organize the 256 narratives (30%) into three locations: educational institution, home, and work. The results are summarized Figure 4.

4.3.1 Educational Institution. The primary location associated with the interaction discovery is an educational institution (144; 17%) which includes both school (129) and university (15). Respondents often received courses and/or exercises about computer literacy (called typing course; technology course, among other names). The **teacher** (87) is often the one responsible of the discovery, teaching the existence of shortcuts either to the whole class or individually during an exercise. 4 respondents provide more explanations: the use of keyboard shortcuts was part of the curriculum to obtain the “IT and Internet” certificate. However, the existence of keyboard shortcuts is not always taught in school. “P1623: [...] *I was the first age group were they didn’t teach any computer skills (like typing) at school, because they assumed you would learn this at home (almost 20 years ago)*”. 20 respondents mentioned **classmates** showing the method during exercises. Surprisingly, 3 respondents discovered keyboard shortcuts as a consequence of a classmate doing a joke: “PP611: *It was a joke. I was told ‘hey, look what happens when you do alt+f4’. So out of curiosity, I closed the program unwittingly, under the laughter of the joker.*”

4.3.2 Home. 94 respondents (11%) reported having discovered the keyboard shortcuts method at home. The discovery often occurs when the learners are doing their homework / school projects (12). The **parents** (69) are in great part responsible of the discovery (father: 33; mother: 12; unspecified: 16) but **siblings** (brother: 9; sister: 6) as well as **classmates** (1) also participate. School thus plays an *indirect* role by facilitating situations at home to transmit knowledge from family (and friends) to the learner about computer skills.

4.3.3 Workplace. Only 13 respondents (1.5% - as a reminder, 28.6% of respondents were not students) reported having discovered the keyboard shortcuts method at the workplace with **colleagues**, but 7 additional respondents (1%) mentioned the discovery occurred in the context of an internship (intersection of work and education).

To sum up, our results highlight the importance and diversity of the social interactions (teacher, classmates, family) in the interaction discovery. They also show the direct (at school) and indirect (at home) role of educational policies.

4.4 When do Users Discover the Keyboard Shortcuts Method?

53 respondents (6%) spontaneously indicated at what age they discovered the keyboard shortcuts method. On average, they were 12 years old ($\sigma = 6$). 26 of them reported having between 8 and 13 years old corresponding to the transition from the elementary to middle school. In addition, 210 respondents (25%) indicated the grade level (elementary school, middle school, etc.) which can be used to estimate the age of the discovery: 48% of the time between 11 and 14 years old (middle school) and 79% of the time if considering the interval 6-14 years old (elementary and middle school). These results are in line with the multiple-choice question “When did you first discover keyboard shortcuts, approximately?” where 739 respondents (86.4%; Mean respondent age: 28, $\sigma = 12$) indicated that the discovery occurred more than five years ago¹⁰. We refined

¹⁰We observe the following frequencies of answers: I do not know (25; 2.9%); Less than a month ago (1; 0.1%); Between a month and a year ago (5; 0.6%) - Mean respondent age: 19 ($\sigma = 2$); Between one and two years ago (14; 1.6%) - Mean respondent age: 22

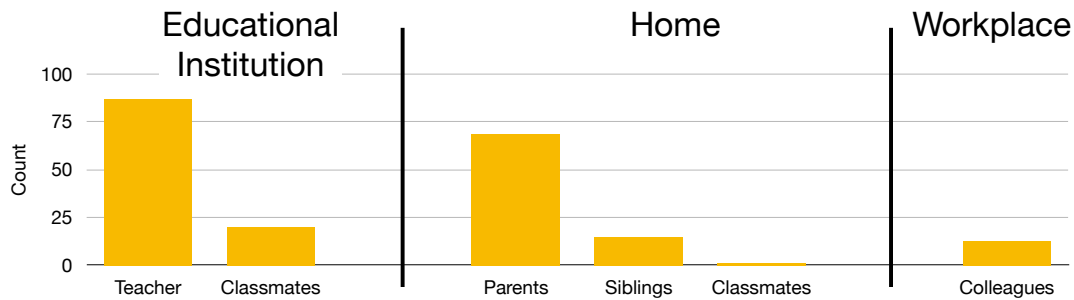


Figure 4: Where Do learning through Social Interactions Occur and With Whom? Our results highlight the importance and diversity of the social interactions (teacher, classmates, family) in the interaction discovery. They also show the direct (at school) and indirect (at home) role of educational policies.

our analysis by considering the age of the respondents: younger and older than 27 years old. Figure 5 shows that 84% of the less than 27 years old first discovered keyboard shortcuts before 14 while it only represents 47% for those who are older than 27. This finding suggests that the young generation discovered the keyboard shortcuts method much earlier than the older generation.

Thus, the interaction discovery often occurs sooner than expected given the target population. However, this result remains in line with the fact that it often occurs at school or at home when doing homework (see section 4.3). Our results also suggest that the age of the discovery depends on participants' birth year, which is in line with the fact that the existence of keyboard shortcuts is not taught in school for all generations (see section 4.3).

4.5 Why Teaching or Seeking Information about Keyboard Shortcuts?

Only few respondents (71; 8%) described the motivations leading to the discovery. We already evoked some motivations, but we synthesize them here explicitly. 43 respondents (5%) reported that **help givers** demonstrated keyboard shortcuts to make learners faster (28), to facilitate/simplify their computer user (8), to be more efficient (2), to avoid making errors (3) or, to be the object of a joke (3; see section 4.3.1). 28 respondents (3%) reported on the **learner** perspective. They mentioned searching how to be faster when interacting with the computer (11), searching to learn more about the system (8) or an application (3) or searching a solution to a technical problem (6; see section 4.1).

4.6 Perception of the Discovery

102 respondents (12%) described their perception of keyboard shortcuts at the moment of discovery. Except three, all of them had a **positive** reaction employing terms such as "Surprise" (13), "Happy" (12), or "Cool" (5). 16 responses included **intense** reactions, employing superlative terms such as "WoW" (2), "Amazing" (3), "Mystified" (2)¹¹. For instance, "P710: *I was amazed by the effectiveness of this incredible invention.*" or "P1192: *I was amazed by this new tool and I was very proud to know them, because I suddenly felt very erudite*

about computers." 53 respondents (6%) spontaneously commented about the immediate perceived benefits of keyboard shortcuts, mentioning "speed" (20), "usefulness/practicality" (19) "make life easier" (4) or "efficiency" (3). Interestingly, the benefits of keyboard shortcuts also appear to be about what they communicate about yourself. Respondents indicated feeling "pride" (1; see the above quote of P1192), being a "scholar" (1), or an "expert in computer science" (1), etc. It remains that three respondents initially perceived keyboard shortcuts negatively, describing them as "useless" (1), "difficult to learn and use" (1) or "confusing" (1). For instance, "P1582: *I hated the idea that there were several paths [menus and keyboard shortcuts] for the same thing, I was afraid it would confuse me. I talked about it to a friend of the family, a computer teacher at university but self-taught, he told me that on the contrary it was brilliant. I was not convinced right away but I ended up thinking it, and I often think of his sentence.*" Regarding the question "Did you start using keyboard shortcuts immediately after [the discovery]?" 680 respondents (80%) answered *Yes*, 80 (9%) answered *No* and 93 (11%) answered *I don't know*. In the narratives, 7 respondents even mentioned immediately searching for more shortcuts. However, 4 reported only using the keyboard shortcut they first discovered (or the pair of keyboard shortcuts: Ctrl+C; Ctrl+V). For instance P1029 learned Ctrl+C; Ctrl+V at school and only use this specific ones until she "*discovers many more keyboard shortcuts*" several years later "*at University*".

In summary, 12% of respondents spontaneously reported the interaction discovery can trigger positive, sometimes intense reactions, supporting adoption. However, usage may be limited to the first few shortcuts discovered.

5 Discussion

We first revisit the two research questions. We then discuss how our results can be explained by, or contribute to, research on interaction discovery and policies supporting digital skills. Finally, we present some implications for design.

5.1 Revisiting the Two Research Questions

RQ1: Which events lead to the interaction discovery of keyboard shortcuts?

($\sigma = 2$); Between two and five years ago (72; 8.4%) - Mean respondent age: 23 ($\sigma = 6$); More than five years ago (739; 86.4%) - Mean respondent age: 28 ($\sigma = 12$).

¹¹We checked that occurrences of superlative was not specific to one country

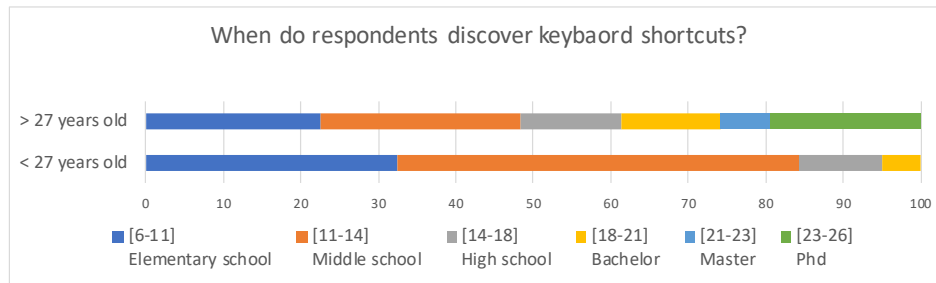


Figure 5: Proportion (%) of interaction discovery of keyboard shortcuts at each grade level by being older or younger than 27 years old.

There is a gap in research on the circumstances leading to the interaction discovery of keyboard shortcuts. Our results confirm our assumption that the situations for the discovery involve extremely frequent commands, in this case “Copy” and “Paste”. The situations also frequently involve a word processor. Other factors include carrying out a specific activity requiring high productivity or technical problems (e.g., unresponsive mouse cursor) forcing users to find workarounds. Surprisingly, we did not observe differences across OS, even if many Linux users reported this method as necessary for “terminal” or “emacs”.

Implication for policy: *Encourage first-time software to introduce aids fostering the interaction discovery of keyboard shortcuts.* Our study suggests word processors are among the most popular types of software when using a personal computer for the first time, and they often play a key role in the interaction discovery of keyboard shortcuts. While all applications would benefit from features that facilitate this discovery, popular first-time software are especially relevant.

More generally, we see these first-time software as a under-exploited channel to develop digital skills. Many initiatives (Digital Skill framework (UNESCO) [44], National Edtech plan (US), Digital Education Plan (EU) [17], Digital Competence Framework for Citizens (DigComp) [16]) are conducted to support the development of digital skills. They primary focus on policies for understanding users need, identifying, measuring and monitoring digital skills or providing dedicated training to children¹², teachers, workers, etc. However, they focus less on encouraging popular and/or first-time software to embed support for the development of digital skills. We see an opportunity for policymakers to provide guidelines and/or incentives to editors of popular / first time software often purchased by schools to favor digital skills support, for instance including interactive mechanisms to favor the discovery (and the learning) of keyboard shortcuts, in combination with the digital skills curriculum.

RQ2: Which aids contribute to the interaction discovery of keyboard shortcuts and how?

Computer aids. Multiple computer aids are available to discover the keyboard shortcuts method: menu items, tooltips, tips, help menus, etc. Users can also rely on external resources, e.g., computer manual or online resources. Our results show that all of these

computer aids were mentioned, at least once, by the respondents. However, the self-discovery through these aids remains rare (6% of all answers). While manuals and online help are rarely consulted [11, 57, 61], we were expecting that repeated exposure to menus would be sufficient to trigger the discovery, or at least stimulate curiosity. Yet, menus and tooltips were reported as the source of discovery only 14 (2%) and 7 (1%) times, respectively. Our findings suggest that computer aids have a limited impact on the interaction discovery of this method.

One interesting finding is that traditional aids are not only difficult to perceive but also to understand (P821; section 4.2.1), in particular the fact that the activation of the multiple keys should be simultaneous. Another finding is about the disabled menu items from Google Docs. This menu “feature” was dedicated to find an alternative to access the system clipboard from a website to protect user privacy. Surprisingly, it appears to foster the interaction discovery of keyboard shortcuts: While the number of occurrences remains small (5), we believe that respondents were much less exposed to disabled menu items than traditional menus.

Social aids. Our study reveals that social interaction plays an important role in the interaction discovery of keyboard shortcuts. Of the 306 respondents describing their interaction discovery, 78% mentioned social interaction, while only 18% discovered keyboard shortcuts by themselves (4% did not specify), i.e., users are four times more likely to discover the keyboard shortcuts method during a social interaction than alone. We further discuss our results below by contrasting them to existing knowledge about social interactions.

Implication for research and design: *Research should focus on the role of social interaction in the adoption and design of interaction techniques.* From the HCI perspective, our results question the role of “individual” computer aids vs. social interaction to discover keyboard shortcuts that has led research in this area. More broadly, this is an invitation for HCI practitioners to consider how to support or trigger social interaction when designing novel interaction techniques. A better understanding of social interactions remains important to elaborate environments that foster the collaborative discovery of interaction techniques.

¹²we discuss the influence of education policies on the discovery of keyboard shortcuts on section 5.2.2

5.2 Understanding the Interaction Discovery of Keyboard Shortcuts as a Social Phenomenon

We now examine our findings on social interactions in the interaction discovery of keyboard shortcuts using three lenses: Over-the-shoulder learning, digital skills in educational policy and Magic as design principle.

5.2.1 Over-The-Shoulder Learning (OTSL). The literature on how users learn to use new digital tools often emphasizes Over-The-Shoulder-Learning (OTSL) [79], happening in proximity, with face-to-face interaction as a trigger of informal learning, and that learning through social interaction occurs in pairs (learner + help giver) [59]. Our findings share some similarities, despite the context being different. Indeed, the interaction discovery of keyboard shortcuts occurs in same-time same-place context, with generally only two people involved. On the other hand, the help giver and the learner often are peers, whereas the literature largely focuses on interactions between colleagues with varying seniority [79]. Our findings also expand what we know about OTSL along five main dimensions.

- (1) *Location.* OTSL is often discussed in the workplace [79]. In contrast, the interactions in our study occur primary at school or at home (section 4.3). Given the results of Peres et al. [68], the location where people learn new keyboard shortcut mappings (workspace) is not same where people discover the method (school, home).
- (2) *Objective.* OTSL often focuses on users with a task to accomplish who are not aware of how this task can be carried out, and thus decide to ask for help [79]. In contrast, keyboard shortcuts is an input method that most of the time offer an alternative way (e.g. menu) to select a command the user is already aware of. As such, our study suggests that the interaction discovery of keyboard shortcuts is rather the result of a *serendipitous* informal learning.
- (3) *Topic.* Previous work mainly discusses “feature” discovery [48, 49, 76]. In contrast, our scenario involves “interaction discovery”, i.e., the discovery of an interaction method, independent of a specific goal.
- (4) *Age.* OTSL discusses many situations involving adults, probably because they occur at the workspace. In contrast, our results reveal that learners (and sometimes the help givers) are children.
- (5) *Diversity.* Another specificity is the diversity of the social interactions, probably because keyboard shortcuts are widely available, and the social interactions occur in different locations. Our context involves active and passive learning as well as formal and informal learning with a diversity of help giver profiles (teacher, a classmate, a friend, a family member or a colleague).

Implication for research: *Research on OTSL should consider the specificity of interaction discovery.*

5.2.2 Educational Policy. We were surprised to find that keyboard shortcuts are discovered at an early age. We initially made the assumption that higher education played a pivotal role in the discovery of this interaction method (see section 3). Indeed, universities around the world have implemented basic computer skills training

for undergraduates and as seen in section 3.1, a recent study suggests that 20% of Japan University students do not know keyboard shortcuts (see Footnote²). Our results do not support our assumption. Instead, the majority of respondents indicated they discovered the keyboard shortcuts method towards the end of elementary school or during middle school, at an average age of 12, and often (18%) in the context at school or during schoolwork. The teacher is often reported as the one teaching keyboard shortcuts, with 4 respondents noting that learning keyboard shortcuts is part of the curriculum at school. For example, one objective of the Computer and Internet certificate in France¹³ includes “*using pointing and input devices*” and online resources include video tutorials about keyboard shortcuts.

Some evidence suggests that the age of the discovery is associated to changes in policies about teaching computing skills [33]. For instance, a 2023 study evaluating the impact of an initiative to teach basic computers skills in primary and secondary schools in France suggests that as many as 95% of 14 years old know of keyboard shortcuts. As personal computers became more widely available in the early 2000s at school [3], we further investigated if *participants entering primary school after the year 2000 discovered keyboard shortcuts at a younger age*. 84% of respondents younger 27 years old, who would been 6 years old in 2000 and entering 1st grade, discovered keyboard shortcuts before turning 14. But only 47% of respondents older than 27 did (Figure 5). That being said, we cannot assume that the existence of keyboard shortcuts is always taught in school as reported by P1623 (see section 4.4). This could also change with younger generations as since the early 2010s tablets have become an equipment of choice for schools [83]. Since tablets do not systematically support keyboard shortcuts [20], this may explain why some students were not aware of them.

Moreover, the respondents reported an indirect role of school in interaction discovery. This includes school projects and homework requiring students to manipulate multiple media (text, images, etc.). For instance, family members may see students preparing a presentation and teach the keyboard shortcut method to save time in repetitive tasks. This is again in line with the narrative of P1263 assuming that computer skills can be learned at home. What we found about this situation points to the need for further study. In responses where interaction discovery occurs during homework, fathers are three times more mentioned than the mother by respondents, even if mothers are usually more involved in homework [42]. While it is consistent with the fact that men are more likely to give computer help [39], it raises questions about home transmissions of a range of interaction skills. Moreover, if institutions indirectly rely on families to teach technologies, it introduces risks of reproducing or amplifying social inequalities [47].

Implication for policy: *Educational policies should continue to be engaged in the teaching of basic computer skills as they have significant impact.* It is illustrated by the fact that we observe differences between age cohorts (see Figure 5). Explicit integration of basic computer skills in education is still helpful and necessary at a time where computers are increasingly used from a young age.

5.2.3 Magic as a Design Principle. Respondents reporting their initial perception of keyboard shortcuts (section 4.6) used words

¹³<https://www.education.gouv.fr/1-evaluation-des-competences-numeriques-6989>

related to *magic*, such as “mystified”, “magical”, or “wizard”. There is a relatively large body of work about magic and technology, e.g., [14, 78] that provides a lens to analyze and understand these reactions. From the participants’ perspective, they are observing an unexpected change in the interface without interaction with the mouse: “P28: *I saw the text appear on the screen without the person using the right-click mouse. I couldn’t understand how he’d done it so quickly*”. While it appears as a simple event, this situation however includes the four main ingredients of magic:

- *surprise*: This notion was spontaneously reported 13 times.
- *ordinary*: It is not the first time than the effect occurs (e.g., making the text appearing), but, it was the first time it was performed in this way. In other words, the effect was produced in a different way than previously.
- *unnatural*. Some participants reported not understanding the interaction. The text appearing (effect) without the use of the mouse breaks the natural laws of causality from the participant perspective.
- *exciting*. Participants reported intense reaction with words such as “Wow” (2), “Amazing” (3), “Awesome” (1). The reason of this excitement is probably because participants immediately perceive the advantages of this method: “speed” (20), or usefulness/practicality (19).

In a common magical stage performance, the audience experiences the magic, but they do not gain the skill of the magician. In our context, the learner witnesses a friend or a parent, etc., and knows it is unlikely there is a “trick” behind it. Therefore, the participant can easily imagine acquiring this skill for real and get a feeling of “power” and “autonomy”. For instance, participants reported to feel as a “little witchcraft” or “a little hacker”.

The link between magic and technology is often discussed about *advanced* technologies such as robots [86], Augmented Reality [10] or mid-air displays [1, 75]. The users discover non-usual devices and the corresponding effects. Our context is different as it relies on a traditional desktop computer with basic keyboard-based interaction. This project thus shows that similar magical phenomena can occur with *traditional* devices. Finally, we believe that leveraging the perception of magic is especially relevant for keyboard shortcuts, as magic has already been used as a source of inspiration for interaction design [19, 75, 78], especially for technologies aimed at children [81].

Implication for research: *Investigating the role of magic on social interactions to better understand the OTSL phenomena.* One challenge of OTSL is to understand why and how the social interactions occur. We argue that magic as a phenomenon can play a role while it has not been investigated in this context. The intense reactions of the participants probably participate to the motivations of the help giver to provide explanations and of the help seeker to ask “teach me!”. Altogether, future work should investigate how magic can inspire the interaction discovery of keyboard shortcuts and more generally other interaction techniques e.g., gesture shortcuts.

5.2.4 Conclusion. The interaction discovery of keyboard shortcuts appeared as an interesting and overlooked use case that extends our understanding of the phenomena related to social interactions and input methods. Future work should consider how these results apply to other methods such as gesture or voice input. Regarding

OTSL, the literature suggests social interaction plays a role in various feature discovery [23, 25, 38]. However, it remains that some empirical studies on gesture-based interaction on smartphone [70] or public displays [34, 85] did not report the role of social interactions for the interaction discovery of this input method. Regarding *Educational policy*, keyboard shortcuts is a singular input method because it is a fundamental skill. It is thus likely that keyboard shortcuts are more often addressed at school than, for instance, gesture or voice input. For instance, we highlighted the role of word processor in the interaction discovery of keyboard shortcuts, but this class of applications generally does not rely on gesture input. The point is thus not the nature of the input method, but whether it is a fundamental digital skill (relevant for the curriculum) or not. Regarding *Magic*, we expect that this design principle can apply to any interaction method.

5.3 Discovery as an interaction phenomenon

Our work also contributes to the line of research on discovery. We discuss how interaction discovery differs from the other types of discovery and what this implies for the design of computer aids.

5.3.1 System, Feature and Interaction Discovery. Mackamul et al. [51] distinguished three types of “discoveries”: system, feature and interaction. Our findings shed new light on the difference between interaction discovery (focus of this article) and system and feature discovery.

- *Interaction vs. System Discovery.* Only few participants mentioned having discovered the method of the keyboard shortcuts when receiving their first computer or when a computer was introduced in their environment (see section 4.3.2). Moreover, none of them suggested in any way that they discovered that the system/computer was interactive at the same time as the keyboard shortcut method. In other words, our study confirms that system and interaction discovery are two different concepts, notably in the context of keyboard shortcut usage.
- *Interaction vs. Feature Discovery.* This distinction is more subtle. Some participants reported having discovered the keyboard shortcut method at the same time as some “features”. Typically, a help giver informs that some commands (features) are available and teach the keyboard shortcut method to execute them. Participants learned the mappings <command; Keyboard shortcut> with their very first use of the keyboard shortcut method. Interestingly, the narratives suggest that some participants did not understand the keyboard shortcut method, as they discovered additional keyboard shortcuts only several years later (P1029). At this time, they (1) assumed these commands required a combination of keys (keyboard shortcut) to be executed but (2) did not understand that this type of interaction can be applied to other commands, i.e. they were not able to generalize the interaction to other commands. These participants thus learned two keyboard shortcuts (feature) without discovering the keyboard shortcut method (interaction), suggesting it is possible to use an interaction method without really discovering it.

Implication for research: *Understanding the cognitive model of users can help to disentangle interaction and feature discoveries.* Do users discover one keyboard shortcut or the keyboard shortcuts interaction method? Future work is necessary to understand to which extent the discovery of the first keyboard shortcut is similar to the interaction discovery: when are users able to generalize the interaction to other commands?

5.3.2 Computer Aids for Discovery. One might also ask whether a computer aid has the same impact on each type of discovery. Both the literature on keyboard shortcut learning and our results indicate that traditional computer aids have limited impact on feature and interaction discoveries. Similarly, both academic studies [29] and the reported experience of our participants indicate the benefits of disabled menu items on feature and interaction discoveries. These results suggest a similar influence of computer aids on feature and interaction discoveries.

Implication for research: *Investigating systematically the impact of advanced computer aids on interaction discovery.* HCI Research should focus on interaction discovery in addition to feature discovery, which received more attention in the literature on command selection. In particular, future work should investigate whether computer aids favoring keyboard shortcut learning can also have an impact on the interaction discovery. Moreover, it would be interesting to study how advanced visual feedforward and feedback, designed to favor individual learning of keyboard shortcuts, can benefit to social interactions. For instance, the Metamorphe Keyboard [6] is a shape-changing keyboard to facilitate the execution of keyboard shortcuts. The physical motions of the keys can attract attention, raise curiosity, favor over-the-shoulder learning, as well as the interaction discovery of keyboard shortcuts.

5.4 Implications for Design

In the previous sections, we mainly provided implications for policy and education targeting policy makers. However, research on keyboard shortcuts is primarily driven by design contributions [5] with the elaboration of many interaction techniques to favor keyboard shortcuts usage [6, 26, 27, 31, 46, 53, 54, 84, 88]. In this section, we thus target HCI designers with implications for design. We demonstrate, through examples how to build on our results to design novel interaction techniques focusing on social interaction rather than individual user.

Make the use of keyboard shortcuts visible during collaborative work. Some participants, as *observers*, did not understand how the active user modified the interface without the mouse (see section 5.2.3). For the majority of keyboard shortcuts, their execution has no visual feedback. Based on OTSL principles, one direction is to modify the visibility of keyboard shortcuts when the computer is used collaboratively, i.e., two users work together on the same computer, to draw the collaborator's attention. Typically, the key combination as well as the command name is displayed on the bottom of the screen (such as in some video tutorial) so that the observer can follow more efficiently what the active user is doing. The mechanism to modify the visibility of keyboard shortcuts can

be adaptable or adaptive. For instance, the active user can change¹⁴, on demand, the visibility of keyboard shortcuts when using the computer collaboratively. This feature could also be controlled by the system. For instance, it would detect (e.g., from the webcam) when two users are working together and automatically increase the visibility of keyboard shortcuts execution. Finally, this feature can be extended to remote collaboration [25], with a visual feedback only rendered on the screen of the person who did not trigger the shortcut. It remains that keyboard shortcuts initially aim at favoring individual productivity with minimal or no visual feedback. The interaction discovery of keyboard shortcuts thus raises a challenging use case highlighting a possible tension between user's productivity and learner's visibility.

Make keyboard shortcut effects magic. As the effect of keyboard shortcuts can be perceived as magic (section 5.2.3), systems can leverage this aspect for both the observer and the active user. The effect should raise the *observer's* curiosity to favor the discovery, i.e., "How did you do that?" or "it is magic!", creating a feeling that the active user is "powerful", thus motivating the reproduction of the effect leading to the interaction discovery. From the *active user* perspective, the objective is similar. The effect should motivate the user to produce the effect in front of observers. It should encourage the perception of having showed-off and to have computer skills, as self-identifying as a "computer expert" (section 4.6) is a source of motivation for becoming a help giver [71, 79].

Create a stage for performances with keyboard shortcuts. Our results showed that pranks are a source of discovery, e.g. asking a friend to execute <Alt+F4> to close their windows (section 4.3.1). This works because of the highly visual and memorable effect, although the consequences of the prank could also lead to associating negative affect to the discovery. Systems can still leverage this source of discovery by reserving a small set of keyboard shortcuts that produce high visual effects and do not impact the internal state of the system. The reason for the the small set of shortcuts (as little as two) is that if systems were to add visual effects to all keyboard shortcuts, this would inevitably distract users' attention. The shortcuts can be the same on all operating systems, so that a user can do a performance regardless of the system. Finally, they should differ enough from common application or system-based keyboard shortcuts to diminish the risks of errors.

Design animated keyboard shortcut cues. One finding was that traditional computer aids can be difficult to understand (P821; section 4.2.1). One direction is to replace static keyboard shortcut cues in Linear menus with dynamic ones. They can better communicate [30] the dynamic of the key-chord activation, in particular that the activation of the multiple keys should be simultaneous (and not sequential; P821). In addition to facilitate the comprehension of keyboard shortcuts, animated cues can also attract attention.

The trigger of the animation might depend on the user familiarity with the software and the command. For instance, if a shortcut (e.g. "Copy") has never been executed on the system, its cue is animated as soon as the user opens the corresponding menu (e.g. "Edit"). Once a shortcut has been executed on the system (interaction

¹⁴operating systems currently provide a configuration panel to create/change keyboard shortcut mappings. This panel can be augmented with a "on screen feedback" option

discovery performed), the animation would not be automatic anymore, but only triggered when hovering/clicking on one keyboard shortcut cue or hovering enough time on one single menu item.

6 Limitations

We identify two main limitations regarding the study:

Structure of the survey. The main question in our survey regarding "Discovery" was "Can you describe when and how you discovered keyboard shortcuts? Was there a particular event or trigger that led to this discovery?". One limitation lies in how the question is framed, as it highlights the "when" and "how" aspects, omitting other elements of the 5W1H framework which could have introduced some bias. The 5W1H framework was the result from an inductive analysis based on our observations rather than a predefined plan¹⁵. Including all components of the 5W1H approach could have led to more detailed and nuanced insights.

Population. A challenge to study the interaction discovery of keyboard shortcuts is to find the "right" participants. For instance, our survey focused on the learner, but future work should also collect narratives from the help givers perspective to understand their motivations and how they perceive the learner's situation. Moreover, University students, in particular those with a background in science, are over-represented in the survey. It would be interesting to broaden the profile of the respondents along two main dimensions: 1) the age by considering both younger respondents to analyze how the discovery evolves over time and the impact of educational policy; 2) a more diverse socio-professional profile. We could then be possible to investigate some interaction effects, e.g. does people with a certain age/background are more likely to rely on social interactions.

7 Conclusion

In this article we investigated the interaction discovery of the keyboard shortcuts method, a fundamental digital skill enhancing productivity which remains under-used. Our large-scale retrospective survey reveals that (1) respondents largely report a social interaction as the event leading to the discovery, with only few reporting the use of computer aids; (2) most participants discover keyboard shortcuts in elementary or middle school, although this depends on the local educational policy; (3) the discovery generally occurs with a teacher, a classmate or family member while doing schoolwork; and, (4) respondents often report a strong emotional reaction to this discovery.

Based on these findings, we contribute in a better understanding of social interactions by highlighting the specificity of our use case on – Over-The-Shoulder (OTSL), Educational policy and magic phenomena. We also contribute in a better understanding of discovery phenomena with interactive systems, – an under-investigated area – by for instance questioning the differences between interaction and feature discovery. Finally, we contribute by providing several design opportunities for the adoption of keyboard shortcuts adoption. It also demonstrates how our empirical findings can inspire the design of novel interaction techniques. Finally, we acknowledged

¹⁵We initially planned a single project investigating different aspects of keyboard shortcut (discovery, learning, memorization, customization). The question about "discovery" was only one among others. However, we did not anticipate the richness of the collected data, in particular regarding the open-field question on discovery.

several limitations all along the manuscript to address in future work such as the need to broaden the profile of the participants to confirm our exploratory study.

Acknowledgements

We thank Baptiste Caramiaux and Johanna McGrenere for their valuable feedback. This research was supported by l'Agence Nationale de la Recherche (ANR) NeuroHCI (ANR-22-CE33-0006-01) and Discovery (ANR-19-CE33-0006) projects. For the purpose of open access, the author has applied a CC-BY public copyright license to any Author Accepted Manuscript (AAM) version arising from this submission.

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A List of the descriptive codes

- WHAT: command (e.g. Ctrl X; Cut); activity (eg. gaming); software (e.g. word processor); hardware (eg. start using a new computer)
- WHY
- HOW: social interaction (e.g. teach, observe, ask), technique (eg. manual, toolip, tip-of-the-day, menu, disable menu, google search)
- WHO : alone; family (e.g. father, mother, parents, brother, sister); teacher; classmate; colleague
- WHERE: home; school, workspace
- WHEN: age; School (eg. elementary, middle, high, university, bachelor, master, internship, phd); work;
- Reaction