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A Survey of Digital Working Conditions of Danish Knowledge Workers

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Abstract. We present a representative survey of the digital working conditions of 466 Danish knowledge workers. We provide data on 1) the hardware and software they use to accomplish their main job activities, 2) the strategies they use to personalise their software, and 3) their digital competences. Our results show that the average Danish knowledge worker primarily uses a laptop and a smartphone to accomplish their work; they use an average of four software applications, mostly developed by large US corporations; they infrequently personalise their software using built-in settings and rarely personalise using plugins, scripts, or reprogramming; they are most capable in using collaboration and communication tools, feel more comfortable formatting other worker's digital content than creating their own, and are confident they can solve most technical issues. These results put into question the relevance of the long-standing Personal Computing dream envisioned by HCI pioneers, highlights the tensions between software applications and the digital sovereignty of the European continent, and emphasise the importance of including digital tools in our conceptualisation and regulation of working conditions.

Introduction

Knowledge workers are the prototypical professional software users, and continue to be the occupational category whose work activities are most supported (or at least mediated) by computers (Bughin et al., 2016). Knowledge workers have also been one of the main user groups studied by HCI researchers, and CSCW in particular. The practice-oriented research program of CSCW, however, has emphasised understanding particular contexts of computer use through interview and observation methods, and limited use has been made of probability-based social surveys (Wallace et al., 2017). Consequently, despite being a centrally recurring figure in HCI studies, little is know about the structural characteristics and conditions of knowledge workers who use computers to accomplish their daily work activities. Such an understanding can help establish generalisable knowledge about computer supported knowledge work and allows us to make informed prioritisations about which issues and communities to focus on using the more traditional interview and observation methods of CSCW research.

This study contributes a representative survey of digital working conditions of Danish knowledge workers – the most digitalised industry in one of Europe's most digital countries (European Comission, 2020). Thematically, this topic was operationalised through the following three sub-questions:

- What hardware and software do knowledge workers use to accomplish their main job activities?
- What strategies do knowledge workers use to personalise their software?
- What level of digital competences do knowledge workers have?

Using the answers to these questions, we paint a portrait of the digital characteristics and working conditions of knowledge workers in Denmark, which can help inform small-sample studies on the impact of digitalisation and discussions about the direction of digital policy to mitigate digital harms.

Background

Informational Capitalism

In the last half century, the political economies of most OECD countries have been transforming from *industrial* capitalism to *informational* capitalism. This qualifying adjective to capitalism follows Castell's seminal "The Rise of the Network Society" (2009), in which he augments the Marxist concept of a society's *mode of production* (capitalism, feudalism) with the idea of a *mode of development* (industrialism, informationalism). The mode of development tries to explain how the same mode of production can have different levels of surplus by identifying what the fundamental element is that increases productivity. In industrial capitalism, Castell argues, the main productive elements are new sources of energy (e.g., steam, electricity, oil) and how effectively they are used throughout production and distribution processes. In informational capitalism, the main source of increased productivity comes from the use of “the technology of knowledge generation, information processing, and symbol communication” (Castells, 2009, p. 17)[1]. As the economy shifts its orientation from energy to information as the primary source of surplus value, the creation, accumulation, and use of that information become the organising principles for capitalist activity.

The Knowledge Economy

The informational capitalist system underpins the emergence of the knowledge economy in the 1990s-2000s: an economic structure whose largest share of growth comes from using knowledge to produce goods and services. Motivated by the slowing down of capital returns on mass-produced physical goods and increase of global competition, many countries committed to the idea of “knowledge” as the new, more efficient asset that would guarantee continued economic growth (examples of knowledge-based capital include patents, intellectual property, brand-equity, innovation research, and, of course, software). We can observe this shift concretely through the policy agendas of the European Commission. In 2000, formalised in the “Lisbon Strategy”, the European Union committed itself to the idea of the information society and aimed to make the EU “the most competitive and dynamic knowledge-based economy” (European Parliament, 2000). In the following “Europe 2020” agenda set out ten years later, it repackaged that aim as the “digital economy”, with initiatives such as the Digital Agenda, the Digital Single Market, and the Grand Coalition for Digital Jobs and Skills. The goal was to create an economy which could “exploit the potential of Information and Communication Technologies in order to foster innovation, economic growth and progress” (European Commission, 2010).

The Knowledge Worker

In knowledge economies, the *knowledge worker* – provocatively called “human capital” – has become the most in-demand commodity, as a large share of the surplus value is assumed to be created when the worker has more knowledge and uses it more effectively. It should be noted that the concept of knowledge work suffers from policy evangelism and lacks an operationalised definition. EU and OECD white papers have variously attempted to capture knowledge work by describing it based on the sector or industry they work in, the activities common in their work, the level of education required, or their occupation category, but none have allowed governments and businesses to measure and intervene effectively in this type of labour (See Brinkley et al., 2009 for a discussion). At the most abstract level knowledge work refers to any work that uses existing information in flexible and innovative ways to produce new information from which value can be

[1] Castell acknowledges that information plays an important role in other modes of development (and production) as well, but argues that the key difference in informationalism is that surplus is created through the application of information on information itself: knowledge is used to increase the quality and production of knowledge, rather than, say, the production of material goods.

extracted. One of the core goals of the European Commission's policies, then, has been to increase the share of knowledge workers in the European labour force. Initiatives have focused on raising the average level of education of the labour force, increasing the share of women in the labour force, and creating opportunities for workers to re-/upskill their digital competences.

The mediating role of digital technologies

The story of the knowledge economy, the "knowledge worker" as an occupation, and digital technologies are deeply connected, stretching back half a century. The application as a model of software first emerged during the late 1970s and early 1980s in the United States, and in large part became a commercially successful mass-market product because it managed to capture the imagination of large corporations and white-collar office workers (Nouwens, 2020). One reason why the knowledge economy became a viable alternative to the manufacturing economy was because computers increased the rate at which information could be produced and processed by orders of magnitude, and because increasingly user-friendly application software made it possible for workers to leverage that capability at scale. The knowledge worker as an occupation continues to be tightly coupled with the effective use of applications as the main tools of production (Nouwens and Klokmose, 2018). To this day, the more knowledge intensive industries continue to be the most digitised (Bughin et al., 2016).

The connection between knowledge work and software design is also foundational to the field of Human-Computer Interaction; the much-venerated line-up of North-American computing pioneers all imagined computers as empowering knowledge tools. Bush (1945) described his Memex as a device that would be an "enlarged intimate supplement to [a person's] memory". Licklider (1960) dreamed of a man-computer symbiosis where "the resulting partnership will think as no human brain has ever thought". Engelbart (1962) believed that "man's[2] problem-solving capability represents possibly the most important resource possessed by a society", so his Augmenting Human Intellect projects tried to increase "the capability of a man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to problems". Kay (1990) called computers intellectual amplifiers that "would actually change the thought patterns of an entire civilization". Kay and Goldberg (1977) imagined software as a "clay of computing" that would let future knowledge workers use the computer to "mold and channel its power to his own needs".

Digital technologies continue to play a central role in the sociotechnical imaginaries surrounding the "Future of Work". If this future is digitally mediated, any analysis of labour-related concerns (e.g., employer-employee relationships, job quality, de/re/upskilling) will now have to consider what role the software's design, development, and deployment plays in the labour process. Here, HCI research and

[2] And, we assume, also other genders.

non-academic studies have left a gap. White papers and policy initiatives by governmental, non-governmental, and commercial research institutes have focused almost entirely on data and skills as the two main components for a digital, globally competitive economy, but curiously ignore the computational tools that workers use on a day-to-day basis to productively leverage those data and skills. HCI research at large takes software design as one of its core subject matters, but its methodological focus on practice-based studies (Wallace et al., 2017) leaves us in the dark about the larger, structural conditions of digital work. This study aims to provide such an initial understanding by contributing a (relatively) large-scale, representative survey of the digital working conditions of knowledge workers in Denmark.

Method

Instrument design

The survey consisted of a mix of 18 open and closed questions, with a possible maximum of 24 questions depending on specific conditional answers. The first question of the survey was used to filter respondents based on their occupation, using the sub-major groups of the 2008 version of the Danish International Standard Classification of Occupations (DISCO-08). The rest of the survey was divided into two sections: one with questions about the respondents' use of digital technologies, and one about their demographic characteristics.

The section about digital technologies consisted of questions about the hardware and software they used to accomplish their work activities (which and how many devices, what operating systems, and which software applications for each device); about whether they adapted their software (how often, and using which strategy); and about their digital competences (e.g., digital communication, collaboration, problem solving). The question regarding software adaptation was conceptually informed by partially-overlapping taxonomies developed by Mørch (1997), Trigg et al. (1987), and MacLean et al. (1990), resulting in four adaptation strategies: using the software's built-in preference settings, through plugins or add-ons, using scripts or macros, and by reprogramming the source code. The questions regarding digital competences were based on the self-assessment survey of the European Commission's Digital Competence Framework, where a participant can rank their competence level (basic–intermediate–advanced) for different skill categories (e.g., information processing, content creation, problem-solving) (see Carretero et al., 2017 for the full scale).

The section about demographic characteristics included questions about employment status (e.g., full-time, self-employed, unemployed, retired), job title, primary work activities, sector (public, private), and industry (e.g., financial and insurance, education, construction). The industry categories were based on the second revision of the Statistical Classification of Economic Activities in the European Community (NACE rev 2) (EUROSTAT, 2008). NACE is a multi-level classification with 21 first level categories, each of which is further broken down into more specific activities. This study used 14 of the top level categories, and a selection of the second level classifications of 5 other categories. Two categories (sections T and U) were not included.

Data collection

Procedure

The data was collected between July 12 and 22, 2018 by YouGov, a global internet survey and data analytics company which maintains a panel of respondents across multiple demographic characteristics. Respondents earn points for completing surveys which can be exchanged for cash, vouchers, or prize draws.

Participants

A total of 3944 respondents between the ages of 18 and 74 were contacted, with quotas on gender, age, and region to reach a nationally representative sample.

		Sample		**Population**
		3945	*100%*	*100%*
Gender	*Female*	2148	54,4	49,8
	Male	1797	45,6	50,2
Age	*18-34*	866	22	30
	35-54	1637	31,5	37,4
	55-74	1442	36,6	32,6
Region	*Capital city*	1260	31,9	31,9
	Sjælland	577	14,6	14,4
	Syddanmark	813	20,6	20,9
	Midtjylland	863	21,9	22,6
	Nordjylland	432	11	10,2

Table I: Unweighted, unfiltered sample and overall population distribution

Variables

In addition to the data gathered through the survey instrument described in *Instrument design* on p.5, the YouGov service included pre-existing background information about the respondents gender, region, age, civil status, and education. The gender data was binary (male, female), and level of education followed the 2015 version of the Danish International Standard Classification of Education (DISCED-15).

Data processing

The sample was cleaned to increase the data quality and processed to make it representative.

The data was cleaned based on 1) occupation, 2) non-response, 3) qualitative data quality, and 4) overall response time. 2474 respondents were screened out because their self-reported occupation did not match our definition of knowledge work (i.e., not falling in the DISCO-08 categories of managers, professionals, and technicians and associate professionals[3]). 450 respondents were removed because they did not complete the survey. Respondents were asked to report which software applications they used to accomplish their main job activities per type of device (laptop, desktop, tablet, smartphone). This qualitative data was processed using fuzzy matching algorithms in OpenRefine[4] and manual inspection, resulting in a standardised list of software. All unreasonable answers (e.g., “asdfghjkl”, “none”) and software names that could not be identified were replaced with the value “-1”. All participants with this response for any single, device-related software question were removed from the data set (n = 525). The median response time for the survey was 7 minutes, with the first quartile at 5 minutes and the third at 10 minutes. All respondents with a response time below 2,5 minutes and above 30 minutes were removed (n = 29). After the cleaning, the final sample size corresponds to 466 knowledge workers.

Post-stratification weights were applied to correct for non-responses using the marginal distribution of occupation category separated into sex (female, male) and sector (public, private). Information about the population was retrieved from Danmark Statistik, the official statistics bureau of the Danish government, specifically from “LONS20: Earnings by occupation, sector, salary, salary earners, components and sex”[5]. The weights were calculated using Iterative Proportional Fitting (IPF). Briefly, IPF is a method that forces the marginal distribution of a sample to match those of the population by applying a weight to each individual row. It does this by fitting the sample to the population using one demographic statistic at a time (e.g., gender). Once completed, it does the same for the next statistic, until the final distribution equals the population’s.

The answers regarding device operating system had to be removed because of a flaw in the conditional logic of the survey that meant respondents were inconsistently shown the question.

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3 “Ledelsesarbejde” i.e., "Management"; “Arbejde, der forudsætter viden på højeste niveau inden for pågældende område” i.e., “Work which requires the highest level of knowledge for the field concerned”; and “Arbejde, der forudsætter viden på mellemniveau” or “Work that requires intermediate level knowledge”.

4 http://openrefine.org/

5 Available here: https://www.dst.dk/en/Statistik/dokumentation/documentationofstatistics/structure-of-earnings

Results

The results are divided into the sections Hardware Working Environment, Software Working Environment, Digital Competences, and Digital Appropriation Strategies.

Hardware Working Environment

Contemporary knowledge workers have a variety of digital devices to choose from to perform their tasks, ranging from more traditional desktop computers, now-common laptops and smartphones, to the still fledgling tablet form factor.

The survey results indicate that the laptop and smartphone are by far the most common tools for the knowledge worker (see Figure 1). Roughly 83,6% uses laptops, and 73,9% uses smartphones for their professional activity. Desktop computers are less common, bit still used by 55,0% of workers, and tablets less popular still, used by just 30,6%.

Overwhelmingly, knowledge workers use just one device per category (83,9%), 7,4% report using two copies of the same device type, dropping to 2,2% for three copies and 1,4% for four copies (see Table II). Interestingly, there appears to be a larger group of workers (5,1%) that use 5 or more of the same device category.

There are clear correlations in the way these devices are combined (see Figure 2). All devices are combined in some way by a considerable number of workers, with the least frequently used pair being the desktop and the tablet, at just shy of one fifth (19,7%) of the respondents. Pretty much all knowledge workers use either a laptop or desktop for their work – only 0,5% use neither. Almost 40% of workers use *both* a desktop and a laptop, but just as many use a desktop with a smartphone (39,3%). Out of all devices, the laptop-smartphone is the most frequent combination, corresponding to 67,6% of workers, although the laptop is also (and more often than the desktop) combined with a tablet, by more than a fourth of all respondents (28,1%).

Number of devices	**Individuals**	**Percentage**
1	951	83,92
2	84	7,38
3	25	2,22
4	16	1,42
5+	57	5,06

Table II: Number of devices of the same type (desktop, laptop, phone, tablet) used by Danish knowledge workers

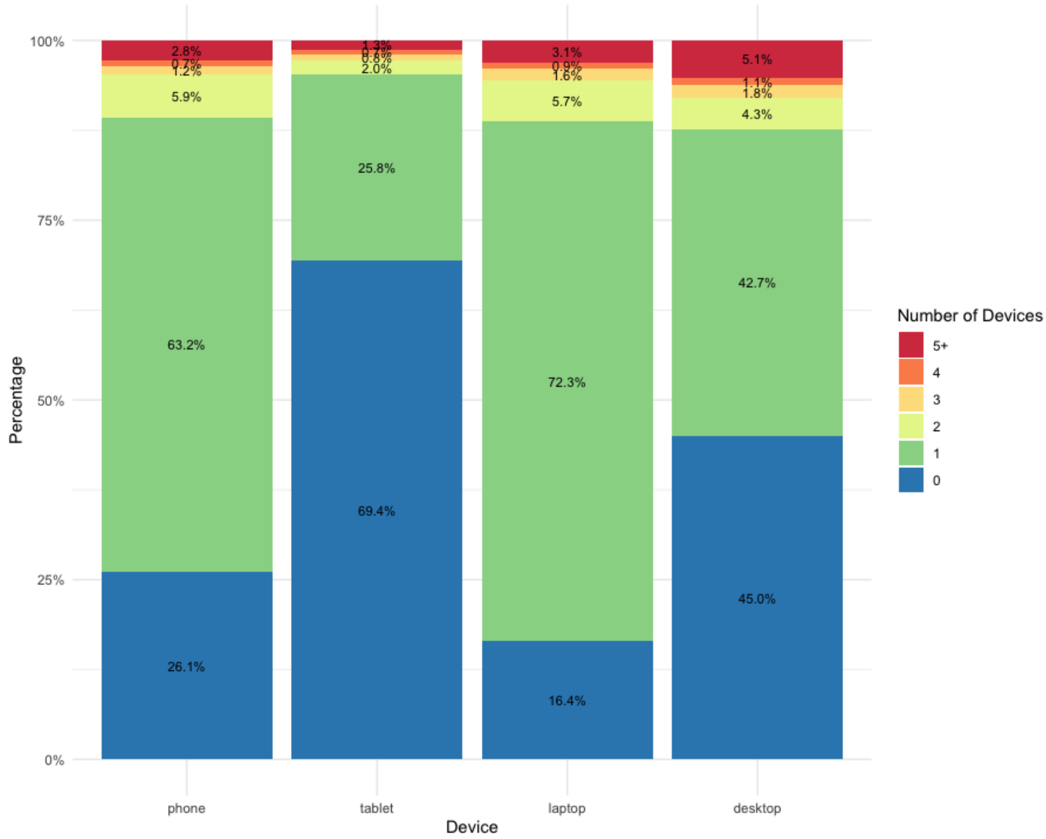

Figure 1: Frequency distribution of different types of devices used by Danish knowledge workers

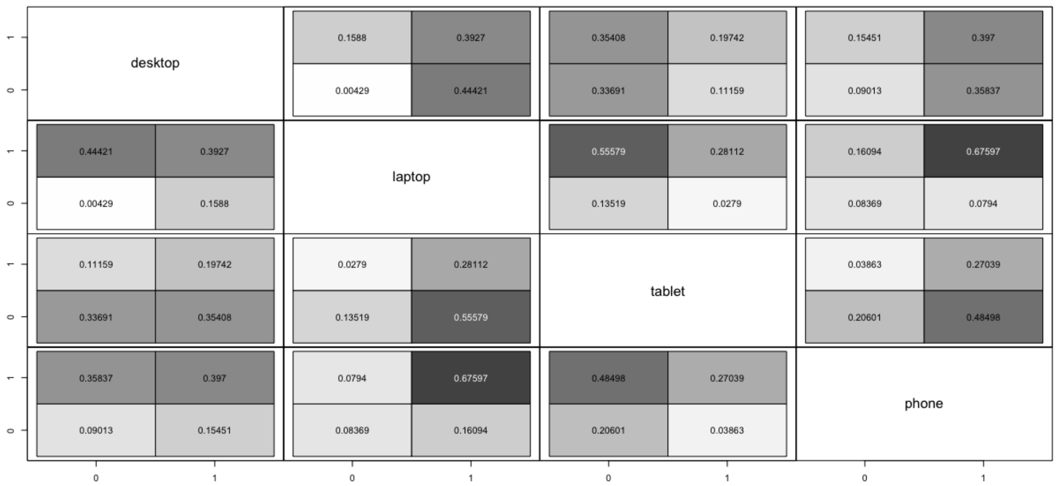

Figure 2: Correlation distribution of different device types by Danish knowledge workers. 0 means the device is not used, 1 means the device is used. The correlations between device and usage can be found by tracing the intersection. The higher the number, the darker the square, the more common the correlation.

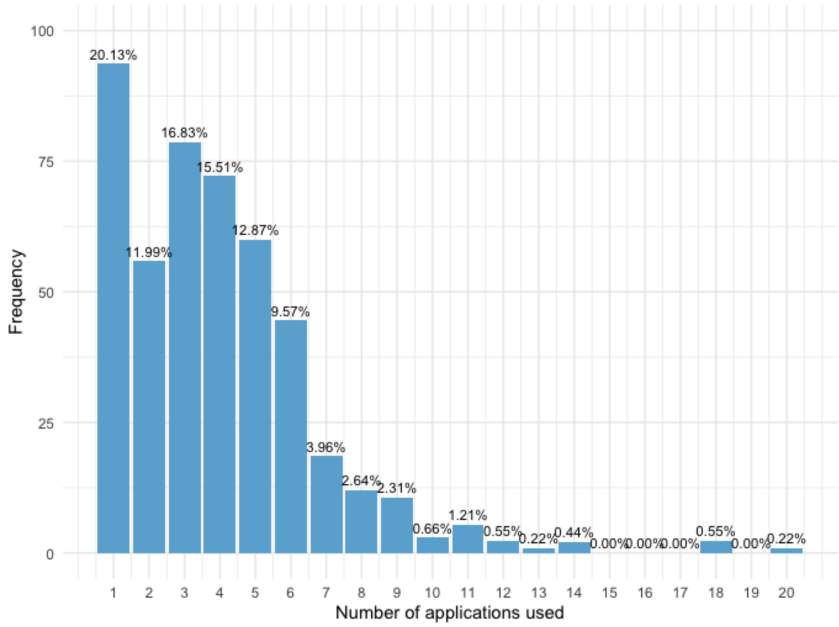

Figure 3: Number of software applications mentioned per respondent as essential to accomplish their work tasks

Software Working Environment

In the 1980s in the United States – the early days of consumer application software – using more than one piece of software as the same time was practically impossible because of hardware limitations such as memory and processing power, but also because of how difficult it was to memorise complicated set of commands for more than a handful of applications (Nouwens, 2020). These days, in large part because of the invention of graphical interfaces with overlapping windows and continuously improving hardware capabilities, it is technologically possible to use a plethora of applications at the same time. This section reports on the software ecosystems of Danish knowledge workers.

Nearly all respondents (464 out of 466) used either a desktop or a laptop. When asked about the software they use for this device that was necessary to accomplish their work tasks, they mentioned a total of 1832 non-unique applications, with a mean of 3,9 and a median of 4 applications per worker. The largest proportion (20,13%) uses just a single application, nearly half uses between one and three (48,95%), and 86,54% of workers use up to six (see Figure 3).

There is considerable homogeneity in the applications used by knowledge workers: the 1832 answers included merely 535 different software (29%), which translates to an average of 1,15 unique applications per respondent in the 3,9 mentioned. The top two mentioned software – MS Word and MS Excel – are used by a quarter (24,89%) of all knowledge workers, and the top ten applications are used by half (see table III). The general pattern appears to be that almost all workers use the same (set of) applications, with the addition of perhaps a single unique one: a long-tailed distribution.

	Software application	Frequency	%	Cum %	Developer	HQ
1	MS Word	256.59	13.92	13.92	Microsoft	US
2	MS Excel	197.19	10.70	24.61	Microsoft	US
3	MS Outlook	131.96	7.16	31.77	Microsoft	US
4	MS Office	91.31	4.95	36.72	Microsoft	US
5	MS PowerPoint	83.12	4.51	41.23	Microsoft	US
6	Google Chrome	52.27	2.83	44.07	Alphabet	US
7	MS Internet Explorer	36.32	1.97	46.04	Microsoft	US
8	MS Office 365	30.46	1.65	47.69	Microsoft	US
9	Adobe Acrobat Reader	19.19	1.04	48.73	Adobe	US
10	MS Visual Studio	18.56	1.01	49.74	Microsoft	US
11	MS Dynamics NAV	18.15	0.98	50.72	Microsoft	US
12	Mozilla Firefox	14.28	0.77	51.49	Mozilla	US
13	MS OneNote	13.81	0.75	52.24	Microsoft	US
14	MS Skype For Business	13.73	0.74	52.99	Microsoft	US
15	Adobe Photoshop	13.14	0.71	53.70	Adobe	US
16	MS SharePoint	13.00	0.70	54.41	Microsoft	US
17	MS Skype	11.73	0.64	55.04	Microsoft	US
18	Adobe CC	10.14	0.55	55.59	Adobe	US
19	SAP	9.89	0.54	56.13	SAP SE	DE
20	MS Paint	9.51	0.52	56.64	Microsoft	US
21	Autodesk AutoCAD	9.35	0.51	57.15	Autodesk	US
22	MS OneDrive	8.53	0.46	57.61	Microsoft	US
23	Google Docs	8.39	0.46	58.07	Alphabet	US
24	MS Access	8.16	0.44	58.51	Microsoft	US
25	Apple Safari	8.03	0.44	58.95	Apple	US
26	Adobe Acrobat Reader XI	7.90	0.43	59.37	Adobe	US
27	Adobe InDesign	7.63	0.41	59.79	Adobe	US
28	Sundhedsplatformen	7.31	0.40	60.19	Epic	US
29	Lotus Notes	6.52	0.35	60.54	IBM	US
30	SAS	6.51	0.35	60.89	SAS Institute	US

Table III: The top 30 most used applications by Danish knowledge workers

The lack of diversity is not just in the choice of software, but also their characteristics. Of the top thirty applications (representing 60,89% of all software used), twenty-nine are made by companies headquartered in the United States and one in Germany. Sixteen – more than half – are designed by Microsoft alone; five by Adobe, and two by Alphabet. Despite the fact that this software is used to support professional activities, many of these applications are general purpose consumer applications, and only seven are marketed as primarily business software (MS Dynamics NAV, MS Skype for Business, MS SharePoint, SAP, MS Access, Sundhedsplatformen, SAS). Additionally, nearly all applications are produced as a mass-market product. The exceptions are MS Sharepoint, Sundhedsplatformen (the healthcare system for the capital region of Denmark), and SAP, which were either built as custom-solutions or market themselves as being highly configurable to the local environment.

The homogeneity in applications used is also evident in which applications are used together, as can be seen in Figure 4: there is just a single cluster centred around MS Word, MS Excel, MS PowerPoint, and MS Outlook. There are no independent clusters disconnected from these, which could have represented alternative constellations beyond the Microsoft ecosystem. The internal connections between Microsoft applications seems to show that the software suite is popular for many of its offerings, or that this model helps boost the popularity of one application based on its bundling with the others. Interestingly, this network effect is not present for the Adobe Suite: Adobe Photoshop and InDesign are not connected at all, hinting that these software are used for tasks or occupations with no overlap.

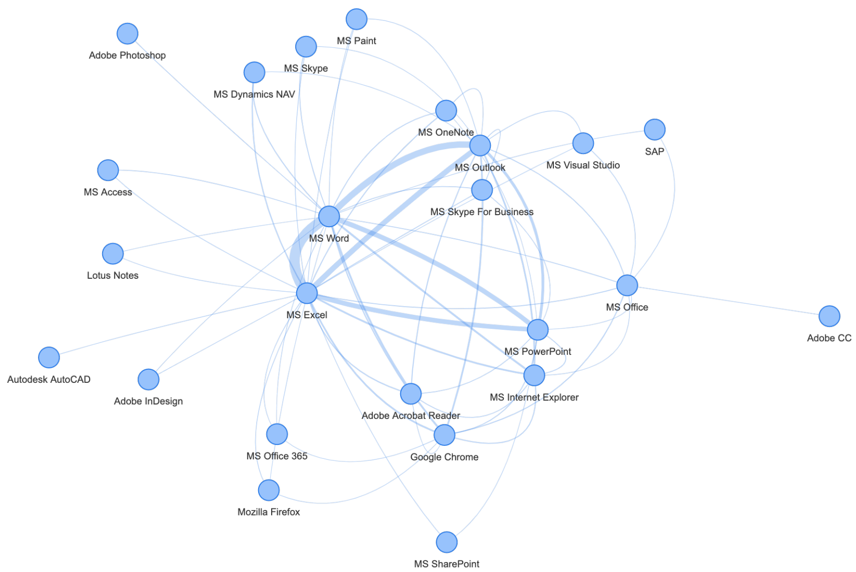

Figure 4: A network visualisation of software applications mentioned together by the same respondent. Only combinations mentioned by at least five workers are included. The thicker the edge connecting two nodes, the more frequently these combinations were mentioned

In the outward connections from the core cluster, we can see that these applications are used in combination with software that supplement its functionality (e.g., MS Word with Adobe Photoshop or MS Skype), but also with applications that one could consider alternatives (e.g., MS Word with Lotus Notes or MS OneNote). Similarly, Google Chrome is used in tandem with Mozilla Firefox and Internet Explorer, but the latter are not used with each other. This kind of friendly coexistence does not extend to all software, however. Some applications are clear competitors; MS Skype is never combined with MS Skype for Business, for example, and neither is MS Dynamics NAV with SAP, indicating these are mutually exclusive.

Ultimately, this network visualisation paints the same picture as the overall frequency distribution: the tool set for the Danish knowledge worker is the Microsoft Office Suite, with MS Word and MS Excel the clear power couple.

Digital Competences

Digital competences, more reductively referred to as digital skills[6] are seen as one of the core requirements for the successful digitalisation of an industry or occupation. How exactly to conceptualise and measure these digital competences, however, is still largely unclear. The European Commission has recently proposed a framework "independent of changes in the functionalities of the tools, software and apps" called DigComp (Carretero et al., 2017), but its fledgling state means there is still little data on the relationship between specific occupations and the presence or requirements of certain competences. This section reports on an early attempt to measure the digital competences of knowledge workers in Denmark.

The respondents of the study have slightly higher levels of digital competences than the country average. According to the Digital Economy and Society Index report of 2020, 58% of Danish residents have at least basic digital skills, and 33% has above basic skills (European Comission, 2020). Compared to this, 34,2% of knowledge workers have at least basic skills, but 54,7% have above basic skills (see Figure 5).

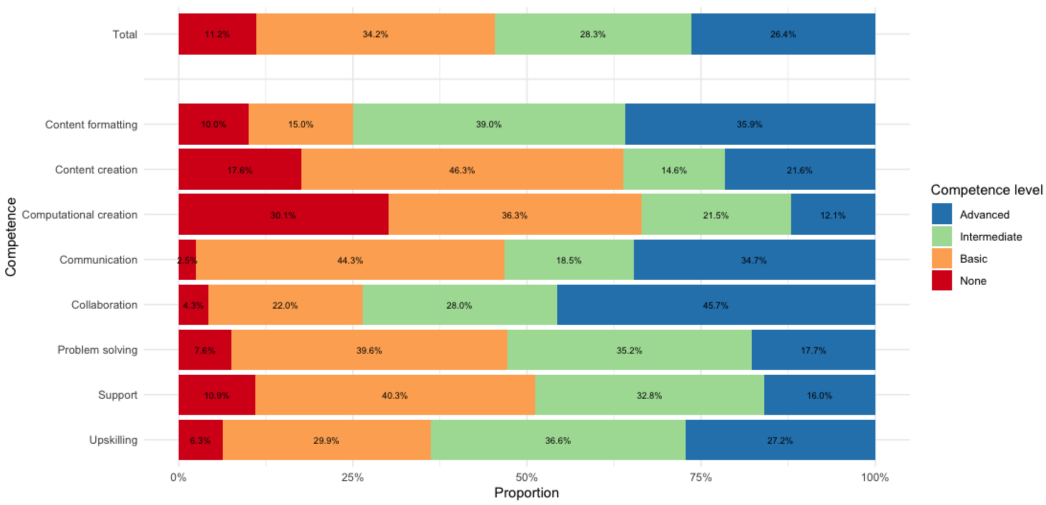

Figure 5: Self-reported digital competences of Danish knowledge workers across eight different types of dimensions

[6] Psychologists conceptualise skills as only one aspect of "the ability to successfully perform a range of tasks to a high level of performance" (Green, 2013). The broader concept of competence also includes "knowledge" and "attitude"

Working with digital content

Digital information is the main material and output of most activities that knowledge workers engage in, which we can see reflected in the digital competences of the respondents. The survey scale used three proxies to measure the ability to work with digital content: *content creation*, *content formatting*, and *computational creation*.

The respondents are most skilled at *content formatting*: nearly 40% is able to at least "apply basic formatting (e.g., insert footnotes, charts, tables)" to content they or others produced, and 35% can "use advanced formatting functions of different tools" such as merging documents of different formats or applying macros. In terms of creating their own content, just short of half of knowledge workers (46,3%) have basic skills and are able to "produce simple digital content in at least one format", but a sizeable 21,6% has advanced skills and is able to produce "produce or modify complex, multimedia content in different formats using a variety of digital platforms, tools, and environments". In terms of *computational content*, this is the dimension where the largest share of workers (30%) report having no competences, in other words, they are not able to "apply and modify simple functions and settings of software and applications". On the other hand, more than a third is able to do this, around 20% knows the basics of one programming language, and 12,1% can use several.

The staggered diminishing of competence levels across these three dimensions meets face-level expectations: editing other people's content is the easiest, followed by creating ones own content. Using more fundamental computer skills such as programming is still far from being the wide-spread competence that most digital policy initiatives are trying to make it. Interesting to note, however, is that despite the obvious importance of creating tangible artefacts that contain the knowledge these workers produced, these three dimensions have the highest overall share of respondents with lower than basic skills.

Communicating and collaborating with others

Knowledge work is often done in (distributed) teams (Mandl et al., 2015) on a per-project basis, requiring good communication and collaboration skills. This characteristic of knowledge work is reflected in the competence distribution of the respondents. The *communication* and *collaboration* dimensions have the lowest proportion of workers without those skills, 2,5% and 4,3% respectively. Collaboration also has the highest proportion of advanced-level workers, with nearly half (45,7%) able to create and manage content using tools such as electronic calendars, project management systems, and online spreadsheets. In terms of communication competences, 44,3% has the basic skills to use a mobile phone, teleconference, send e-mails, or use chat systems. Roughly a third (34,7%) indicates they "actively use a wide range of communication tools", such as social networks and blogs.

Overcoming and adapting

By some definitions, knowledge work can be characterised by non-routine tasks that require continuous innovation and creativity (Brinkley et al., 2009). In terms of the use of digital tools, this would require searching for new ways to do things, update ones digital skills in order to explore new ways of working, and being able to handle any technical problems when they arise. The three dimensions associated with these practices – *upskilling*, *problem solving*, and *support* – are the three dimensions that collectively the largest proportion of knowledge workers have intermediate level skills in. Roughly one third is able to "solve most of the more frequent problems" by "exploring the settings and options of programs or tools". Around one third is "aware" that they need to update their digital skills regulary, more than a third is "regularly" doing so, and a bit more than a quarter does this "frequently".

Digital Appropriation Strategies

One of the fundamental tenets of HCI research in general, and practice-oriented CSCW in particular, is that there always exists a gap between the design of a standardised piece of software and the idiosyncratic work practices of the individual/community. This section describes the strategies knowledge workers use to customise their digital tools, and how frequently they use them.

The respondents were asked how often they used the built-in settings, plugins/add-ons, scripts, or reprogramming to adapt their software (see Figure 6). Considering the use of these strategies from a binary perspective, we can observe that 90,87% have used the built-in settings, 59,41% have used plugins/add-ons, 42,47% have used scripts, and 26,64% have used reprogramming.

When going beyond *whether* workers adapt their software and instead consider *how frequently* they do this, the data follows a similar stepwise reduction. A considerable number of respondents (68,42%) use the built-in settings about half the time or more often to adopt their software, but this proportion shrinks to 20,03% for plugins or add-ons, 11,66% for scripts, and a marginal 2,64% for reprogramming. As we move between strategies, which can be considered to grow more complex, the proportion of workers who never use that strategy increases. In an analogous pattern, as the frequency of using scripts or reprogramming increases, the proportion of respondents is reduced. The use of scripts or add-ons, however, behaves slightly different. Here, more workers "sometimes" use this strategy (24,20%) than "almost never" (14,96%). Of all strategies, only the use of built-in settings is approximately evenly spread across different frequencies (from *Never* to *Always*).

The use of certain strategies appear to be correlated with each other in unexpected ways (see Figure 7). Considering the staggered decrease of use going from settings to reprogramming, one would assume that between two strategies, the less complex one is most strongly correlated with the non-use of the other. In other words, if a worker uses the built-in settings, they are more likely to not use

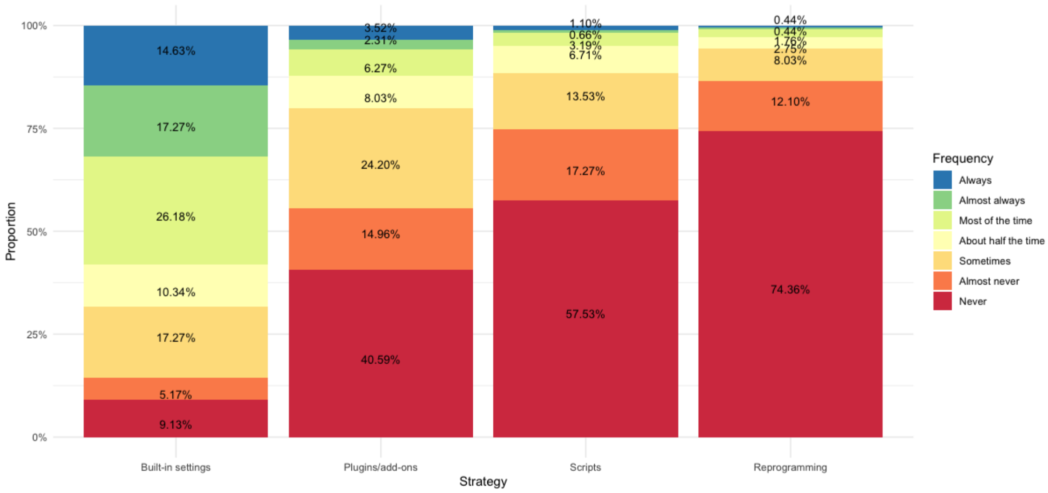

Figure 6: Different software adaptation strategies and how frequently they are used by Danish knowledge workers

plugins. If they use scripts, they are more likely to not use reprogramming. This does not appear to be the case. Instead, workers that use the built-in settings are most likely to also use plugins, are equally likely to use or not use scripts, and most likely to not use reprogramming. Respondents are roughly just as likely to use plugins and scripting, as they are to use neither; and if they use scripts, they are equally likely to use or not use reprogramming. These correlations suggest that there is some independence between the use of different adaptation strategies: it is not simply a matter of those who use reprogramming also being the ones who use scripting, plugins, and built-in settings. Instead, the data hints at clusters of respondents who combine certain strategies in ways that do not follow their complexity.

Discussion

Summarising the results, we can paint the following picture: the average Danish knowledge worker uses a single laptop and smartphone device to accomplish their work tasks. On their main computer, they use approximately four software applications to accomplish their main job tasks. Like almost all their colleagues, they mostly use MS Word, MS Excel, and MS Outlook, and a single, unique application. When using these applications, they most of the time take advantage of the built-in settings to customise it to their preference, and rarely (if ever) use plugins, scripts, or reprogramming. Overall, they are comfortable using a computer and know a couple of different ways to approach the same problem using software tools, although there are still areas they are less competent in. They are more skilled at formatting other worker's digital content than creating their own; are comfortable using collaborative tools and know how to communicate with their

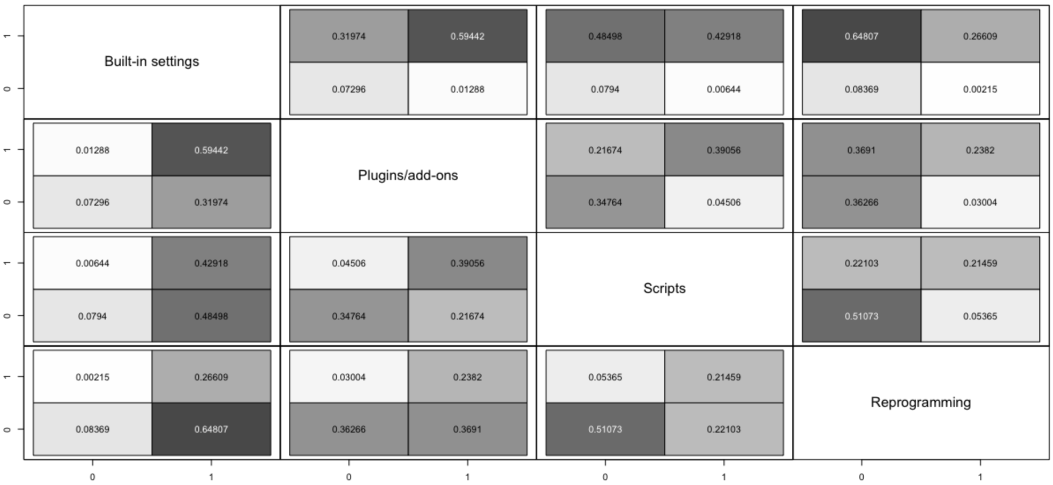

Figure 7: Correlation distribution of different adaptation strategies by Danish knowledge workers. 0 means the strategy is not used, 1 means it is used. The correlations between strategies can be found by tracing their intersection. The higher the number, the darker the square, the more common the correlation.

colleagues using the basic features of a variety of media. If they run into technical problems, they are capable at solving most issues or know how to find support.

The dream of Personal Computing

The computer as an intimate partner, a supplement to the human brain, that might "elevate one's spirit" (Bush, 1945) is a foundational dream of Human-Computer Interaction. Personal accounts of early hobbyists and hackers of the personal computer in the 1970s seem to suggest that such symbiosis were formed, but historiographic analyses of PC magazines from 1980 to 1984 shows how this imagination and relationship transformed as the computer became a mass-market consumer product and the people buying it became *users* (Nooney et al., 2020): this demographic was more interested in the purposes for which personal computing could be used as a tool, rather than seeing the device as a reprogrammable universal machine. Our data confirms this tendency and shows that most knowledge workers are *users* of ready-made software that rarely tailor beyond the built-in preferences.

The commodification of software – the emergence of *Software as an Application* – and the subsequent expansion of its user base with their own diverse visions for the computer (to the chagrin of some computing researchers (Kay, 2007)), requires us to take stock of HCI's dream of personal computing. How close are we to achieving that human-computer interaction? Is it still a worthwhile pursuit, or should it be repositioned as a historic interest rather than one of the main goals of the research community? What design characteristics of contemporary application software is inviting or inhibiting this kind of relationship? What are the wider, structural conditions – the character of the software industry, the increasing geopolitical role of software – that shape the nature of our connection to applications?

As the application software industry emerged, it both stimulated and pursued the imaginary of people as *users of computers* rather than *programmers of computers*, and of software as a *product* rather than a *medium*. One of the early barriers limiting the size of the software product market was how difficult it was to use multiple applications at the same time, and most of the 1980s and early 1990s was devoted to exploring different paths towards the holy-grail of software multi-tasking: application families, integrated packages, windowed application managers, component software, etc (Nouwens, 2020). Although Moore's law has mostly eliminated hardware limitations and the graphical user interface has reduced the cognitive strain of learning how to use more than a handful of software, the data from this survey shows that users – or, at least, knowledge workers – still only use between one and six applications. Why is that? Is a few applications simply sufficient to accomplish most work tasks? Or are there specific barriers that inhibit the use of more applications, such as the lack of interoperability or entrenched proprietary document formats? Is it still too difficult to learn how to effectively use more applications, despite the GUI? Or are they not individual factors, but limitations that arise in collaboration with others?

Another question that arises from seeing which applications are used by knowledge workers is why, despite having largely stayed the same since the 1990s, the Microsoft Office Suite still dominates user's application ecosystem. Is this simply a matter of "the end of history": has Microsoft perfect the designs of word processing, spreadsheet, and presentation software, and are there no reasons to switch to alternative applications? Or are there other forces at play, such as organisational legacies, high (data and skill-based) personal investments, consumer lock-in, or network effect? We humbly suggest these questions as interesting avenues for CSCW researchers to pursue using the qualitative, practice-oriented methods that is the community's tradition.

The global power dynamics of software

Individual, day to day experiences with the computer inform what Rosenberger (2009) calls "relational strategies": the learned ideas about and habits around how to relate to a technology that is stable in a particular way. This survey of application use in Danish knowledge work paints a picture of a digital ecosystem monopolised by a few US American corporations, with a handful of software being responsible for the ideas and habits we develop about computing at large. Rather than the computer as the "intimate supplement" imagined by Bush (1945) the "[hu]man-computer symbiosis" by Licklider (1960) or software as a "clay of computing" by Kay and Goldberg (1977), the paradigmatic application model of software seems to be teaching people that a computer contains turn-key products of pre-packaged functionality that *you adapt to*, rather than *adapting it to you*. When placed in the context of the workplace, this points to a contentious power distribution between the producers and users of software: the predominance of turn key applications leaves little room for workplace democracy to have any control over how software is shaped and used. With the European Union looking towards the digital economy as the future of the continent, it needs to decide whether it is comfortable letting US-based companies have monopolistic control over the artefacts that mediate and cocreate the European labour force.

The future role of digital working conditions

Regulations of working environments are historically rooted in the physical context that work is performed, designed to protect against dangerous equipment and materials. Since then, a large share of physical labour has become automated or outsourced to other parts of the world, and knowledge and service work has became more prevalent in post-industrial economies. Working environment regulations have evolved with it, now also taking psychological factors that affect worker's well-being into account. The Danish Working Environment Act, for example, takes the broadly construed position that "individual workplaces should be designed in a way which will prevent employees from being forced to leave the labour market due to attrition and stress" (Arbejdstilsynet, nd).

As more and more work becomes digitally mediated, driven on by the sociotechnical imaginary of the digitalised economy and society as the new cornucopia of continued growth and social progress, our conceptualisation of working environments should shift with it to consider the ways digital technologies intersect with the physical and psychological well-being of workers. One could argue that these two higher-order categories are broad enough to also capture the impacts of digital technologies, but without comparative studies between traditional instruments to measure working environments and those that focus specifically on software design, we cannot say for certain whether, or how much, is accounted for. Tentative first steps have been taken across a variety of disciplinary venues, centred around the concept of *technostress*: stress that individuals experience due to their use of information systems. Ayyagari et al. (2011) describe how the always-on nature of technology, the constant changing nature of software, and the increased ability for worker surveillance are antecedents for later stress. Fuglseth and Sørebø (2014) show that the perceived complexity of the software and constant changes are the biggest contributors to technostress, but that technical support and mechanisms that increase worker's digital literacy can have inhibiting effects. Berg-Beckhoff et al. (2017) present conflicting results, showing how digital technologies are correlated with stress in cross-sectional studies (which explores bi-directional relations), but not in intervention studies (which would reveal causal relations). However, they do find an association between digital tools and burnout, mostly present in middle-aged working populations. Tarafdar et al. (2019) add a speculative optimistic note, and argues against the prevailing literature to claim that technostress might lead to positive outcomes as well, such as greater effectiveness and innovation. HCI has a clear contribution to make to issues surrounding digital technologies and workplace environments. Current work exploring these questions is not as attuned to interface design, or software models more broadly. The data provided by this study has taken a first step, by trying to representatively capture the hardware and software conditions, and the digital competences and practices related to those factors of Danish knowledge workers.

A better understanding of which elements of software design are causally related to both positive and negative digital working environments can contributed to two agendas. One the one hand, this knowledge can be used to inform digitalisation policies, regulatory initiatives, and – importantly – the instruments currently used to monitor workplace environments. On the other hand, data on which software design elements create or inhibit negative psycho-social experiences can be used to inform the (re)design of commonly used applications. For both agendas, the data from this study can be used to decide which stakeholders to prioritise. Considering the dominance of US American-developed software, and specifically the monopolising position of Microsoft, any regulatory or design interventions should be targeted towards these actors.

Limitations

The results from this study should be considered with the following limitations in mind. First and foremost, the data was collected using the commercial survey service YouGov, so the quality of that data is in large part determined by the quality of the panel of respondents they have recruited. In the process of cleaning the data, more than half of the sample was discarded. Although the design of the survey instrument also plays a role, and a conservative filtering method was used, this is still a considerable proportion of the data corpus, and affects the overall confidence in the results. However, it should be noted that the overall distributions of the answers to the different questions did not always show a considerable change before and after the cleaning (with the exception of the questions about digital competences).

In addition to the quality of the remaining data, the data cleaning also had consequences for the overall sample size, reduced to merely 466 participants. Although the marginal distributions of the sample were close to those of the population, and iterative proportional fitting further aligned the two, the small sample size means that we should be careful when considering the generalisability of the results.

Lastly, the survey instrument was designed for this study, but not validated to confirm that the questions properly captured the intended variables. However, most of the questions included were taken from pre-existing and widely used surveys

Conclusion

The field of Computer Supported Cooperative Work specialises in providing thick descriptions of technologically-mediated work practices. This paper contributes a representative survey about the digital characteristics and working conditions of knowledge workers in Denmark, to contextualise such qualitative data with statistical insights. We collected data on the hardware and software used by knowledge workers, their digital competences, and the extent to which they adapt their software.

The analysis show that the hardware and software used by Danish knowledge workers are largely homogeneous. The results demonstrate that products from a few US-based companies have become the de facto standard for computer-mediated knowledge work, and that adaptation of software beyond changing built-in preferences rarely happens.

Considering that the need for local adaptation of software is a basic premise of CSCW research, we highly encourage future work that can shed more light on this lack of software customisation: is the software simply good enough, or are the costs of appropriation (in terms of time, training, risk of obsolescence) too high? We hope this study encourages more CSCW researchers to consider large-scale survey methods as a worthwhile tool to address these and other questions that provide a high-level overview of the status quo of computer supported work. While their results might not always be shockingly surprising, they complement our qualitatively informed intuitions with detailed empirical data.

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