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FITTS' LAW AS AN EDUCATION RESOURCE FOR HUMAN-COMPUTER INTERACTION IN COMPUTER SCIENCE CURRICULA

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Abstract
Fitts' Law is, more often than not, thought of as standard knowledge in the field of Human-Computer Interaction. However, in many occasions, interface components are being built by professionals with little or no knowledge of HCI principles (e.g., software menus are often being built by software developers with no designer input). How much appreciation of Fitts' Law exists among developers, and how does it affect our collaboration with them and the software they build and we use? To help answer this question, a survey among 65 designers and developers was conducted, as well as an analysis of the Computer Science undergraduate curricula from 94 internationally high-ranked universities. The contribution of this paper is twofold: firstly, treating Fitts' Law as an Open Educational Resource and, secondly, the analysis identified gaps that extend beyond HCI Education and fall in the sphere of Epistemology.

Keywords: Fitts' law; HCI; education; epistemology.

1. INTRODUCTION

We all know what Fitts' Law is. Or do we? The answer may depend on who "we" are, and on how we understand scientific laws. Fitts' Law is a *sine qua non* in HCI Education. However, many—if not most—practitioners in the field would not have undertaken traditional HCI Education: they would originate from either non-technical backgrounds such as (non-applied) psychology and design, or from engineering and computing. The interdisciplinarity of HCI practitioners has offered a great deal to the field, and many courses in the aforementioned fields offer elective HCI modules; however, it is not expected that a graduate of these courses would be necessarily aware of what HCI is. Working in groups where the majority of members have little or no awareness of HCI can hinder communication around a design problem—or a proposed solution thereof—, and can potentially lead to designing for poor user experiences.

Finding a balance between the desired interdisciplinarity of a group and a mismatch in understanding is no easy task. Difficulties are manifest in a large sub-field of HCI, which is software construction. The designer/developer workflow is a constant example of workplace friction, and a rich source of inspiration for imaginative start-ups that produce tools promising to ease the workflow. While an increasing number of organisations values design more than in the past and the number of start-ups with designer founders is reportedly increasing, the conceptual mismatch in the designer/developer workflow is still present.

In this paper, the aim is to consider Fitts' Law as an example of the designer/developer mismatch. Do designers and developers perceive Fitts' Law in different ways? If yes, is this a result of HCI Education? If not, what can be still said about the apparent conceptual mismatch?

2. RELATED WORK

Fitts, after having worked for a number of years with the U.S. Air Force on the psychological aspects of aircraft displays (Fitts, 1947), generalised his work on controlling the amplitude of movement. His experimental work was seminal and has resulted in a series of laws (Fitts, 1992). The law describing how the response time of controlling a target is proportional to the distance from and the size of the target has been named the “Fitts’ Law” and been considered as a law of paramount importance for the field of Human-Computer Interaction (Thimbleby, 2013).

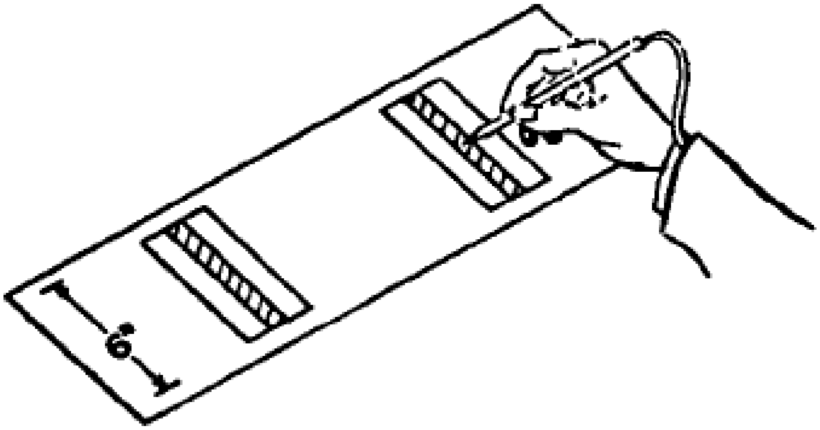
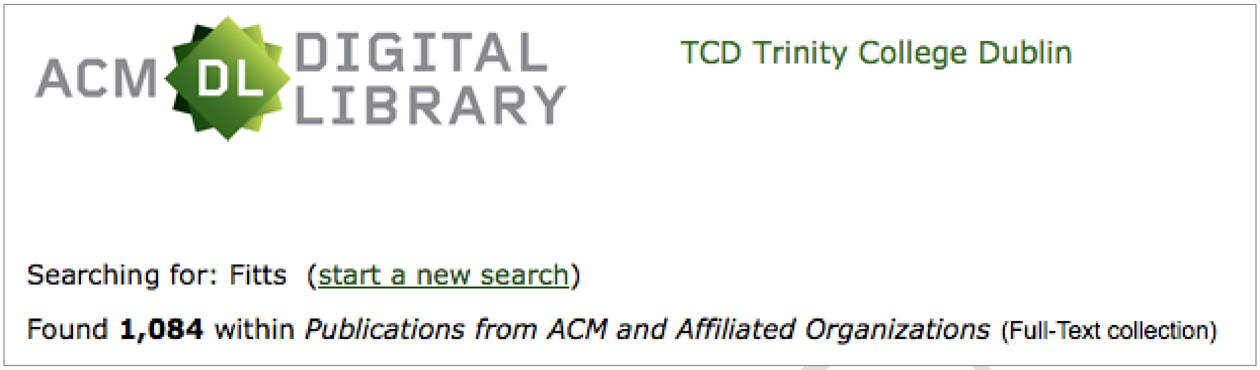


Figure 1. Reciprocal tapping apparatus. The task was to hit the center plate in each group alternately without touching either side (error) plate.

Figure 1. A figure from the original Fitts’ experiment (Public Domain) (Fitts, 1992).

Fitts’ Law has played a big role in HCI research, as it has been viewed through multiple lenses. It has been shown that the Law holds for tablets; for hand-gesture detection; for tracking certain eye movements; for touchpads; for (some) motion kinetics; or for screen-edge pointing (Appert, Chapuis, and Beaudouin-Lafon, 2008), (Brown, M. A., Stuerzlinger, & Mendonça Filho, 2014), (MacKenzie and Oniszczak, 1998), (Mandryk and Lough, 2011), (Surakka, Illi, and Isokoski, 2004). It has been shown not to hold for some radial menus (Friedlander, Schlueter, and Mantei, 1998). It has been viewed as a time/error tradeoff, as a research and design tool in HCI, or as a research tool for the perception of user performance (Guiard and Perrault, 2011), (MacKenzie, 1992), (Nicosia, Oulasvirta, and Kristensson, 2014). Others have focused on the specific variations of the formula that expresses Fitts’ Law (Drewes, 2010). A multitude of academic research articles and blog-posts have been written about it.



Searching for: Fitts (start a new search)

Found **1,084** within *Publications from ACM and Affiliated Organizations* (Full-Text collection)

Figure 2. A search for "Fitts" in the ACM Digital Library is indicative of the popularity of Fitts' Law.

With regard to the field of Education, previous research has built upon traditional HCI for Education work to show that research projects around experimenting with laws such as Fitts' one are beneficial to CS undergraduate students (Pastel, 2005).

More broadly speaking, some previous work describes case studies where HCI has been integrated, in one way or another, in a CS curriculum (Chan, Wolfe, and Fang, 2002), (Cockburn and Bell, 1998), (Douglas, Tremaine, Leventhal, Wills, and Manaris, 2002), (Fischer, 2008), (Greenberg, 1996), (Moore and Lottridge, 2010), (Pastel, Brown, C., Woller-Carter, and Kumar, 2012), (Rusu, C., Rusu, V., Roncagliolo, and Rubio, 2007). The need for interdisciplinarity has been emphasised; specifically, the joint ACM/IEEE CS 2013 curriculum especially recognises the need to "provide students with the flexibility to work across many disciplines" and to cover various knowledge areas in introductory courses (it specifically includes HCI in both Tier 1 and Tier 2, which is great) (The Joint Task Force on Computing Curricula – Association for Computing Machinery / IEEE-Computer Society, 2013).

Thus, a study on the actual situation in CS curricula seems to be necessary; is the recommendation of the CS2013 curriculum to include HCI in Tier 1 Core modules actually being implemented? Such a study is presented below.

3. FITTS' LAW BEYOND HCI EDUCATION

A study on the inclusion of HCI in CS curricula should try to address the following two issues. Firstly, do HCI-related concepts appear in Tier 1 modules? Secondly, what are the implications of not including HCI in core CS?

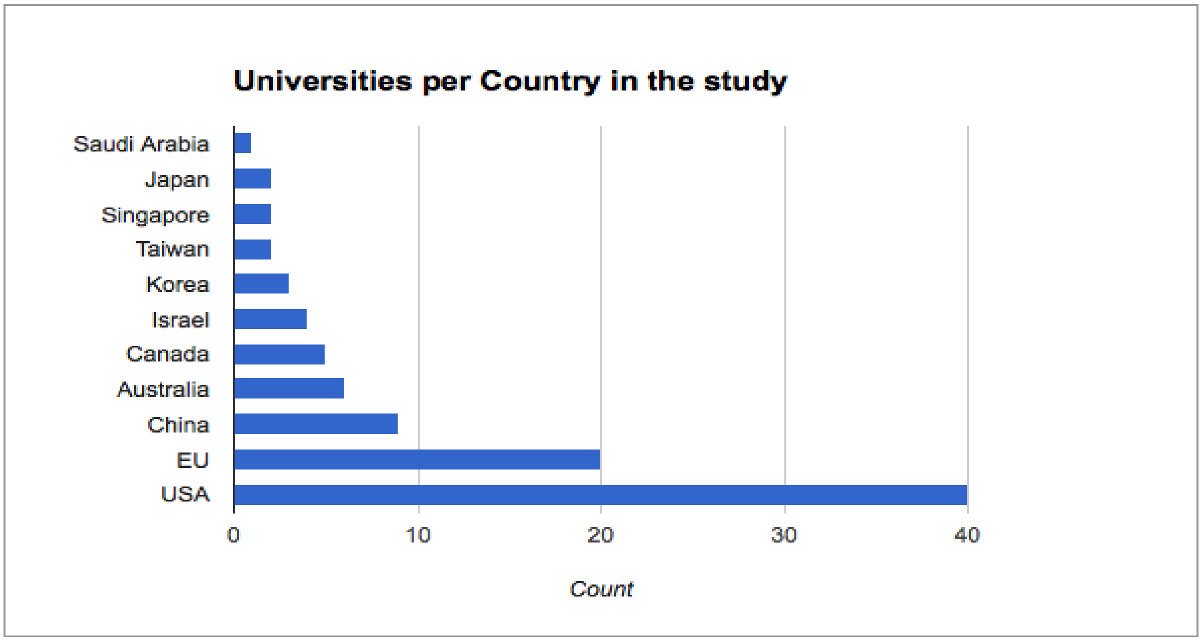
3.1 HCI Education in CS Curricula

To investigate if HCI-related concepts appear in CS core modules the following approach was followed.

Firstly, a list of universities was compiled by triangulating the results of three prominent university-ranking providers [1]. The top 75 universities in CS from the 2014 Shanghai Academic Rankings, the top 50 universities from the 2014 QS University Rankings in CS and Information Systems, and the top 50 universities from the 2014-2015 Times Higher Education ranking in Engineering and Technology. This list yielded a list of 94 universities from 11 countries. For the sake of simplicity (no political connotations should be drawn from this), universities from the EU and Switzerland were filed under "EU" as they use the structures of the European Higher Education Authority (EHEA) and, similarly, universities from China and Hong Kong were filed under "China".

For these 94 universities, their CS curricula were located through their websites. One undergraduate Bachelor's or Major in CS program per university was chosen to be included in the study. Computer Engineering, Information Systems, Interaction Design, or Multimedia Design programs were excluded, as they are out of scope for this study.

Then, for each CS course the following information was collected. Firstly, if the course offers an introductory course to CS, in which various fields of computing are represented. Possible answers are {*yes*, *no*, *programming*}, where "yes" means that an Introduction to CS exists and covers various CS fields, "no" that such an introduction to CS does not exist, and "programming" that an introduction to problem solving exists, but is entirely focused on algorithmic thinking and using a programming language. Secondly, data were collected with regard to the course including HCI topics in the introductory CS modules, as an obligatory HCI module, as an elective module, or not at all.



[1] Disclosure: I participated in the 2014 QS World University Rankings Survey as a respondent.

Figure 3. A graph of the—skewed—distribution of the top ranked universities for CS per country. Triangulating rankings from three different providers composed the list.

Limitations in data gathering resulted in analysing 82 out of 94 programs. Some programs offered information only in the native language of the country where they are offered: machine translation helped successfully with some of these, but not all curricula pages could be located. Another limitation was the lack of detailed descriptions in some courses, which may have mentioned that they offer an introductory CS course, but its syllabus is not publically available. Finally, one website was not available due to technical failures during data collection.

All effort was put into gathering the latest information, namely for the 2014-2015 academic year. An apparent weakness of this method is that it may identify current patterns is curricula, but the direction towards these curricula will be developed is not clear. Thus, a university that currently considers moving to the CS2013 curriculum, and one that does not will appear the same, if their current offerings are the same. However, considerations to change the curriculum towards CS2013 are rarely announced in public, making such a data collection almost impossible.

The list of universities and the full data are available at: http://bit.ly/1JYF03A

The results of the data analysis are presented in the next section. Before that, the following sub-section describes the second part of the study around the implications of excluding HCI from core CS curricula.

3.2 Designers' and Developers' Perception of Fitts' Law

To define all implications of excluding HCI from Tier 1 CS courses in no easy task. For this reason, this study is limited in identifying a small, but important, subset of the HCI body of knowledge: its iconic Fitts' Law.

The rationale originates from a real case in Learnovate Centre around an educational software application. On an in-house re-design of a content-composition application for Windows 8.1 bearing Microsoft Surface devices, a discussion arose among our designers and developers around the design and implementation of the navigation menu. The original impression was that the native menu (see Figure 4) had to be implemented, but eventually a different mechanism was designed and implemented.

However, during the discussion around the native menu, various web searches revealed that many developers had a flawed perception about what Fitts' Law is. This flawed perception seemed to have affected the implementation of menus by the said developers.

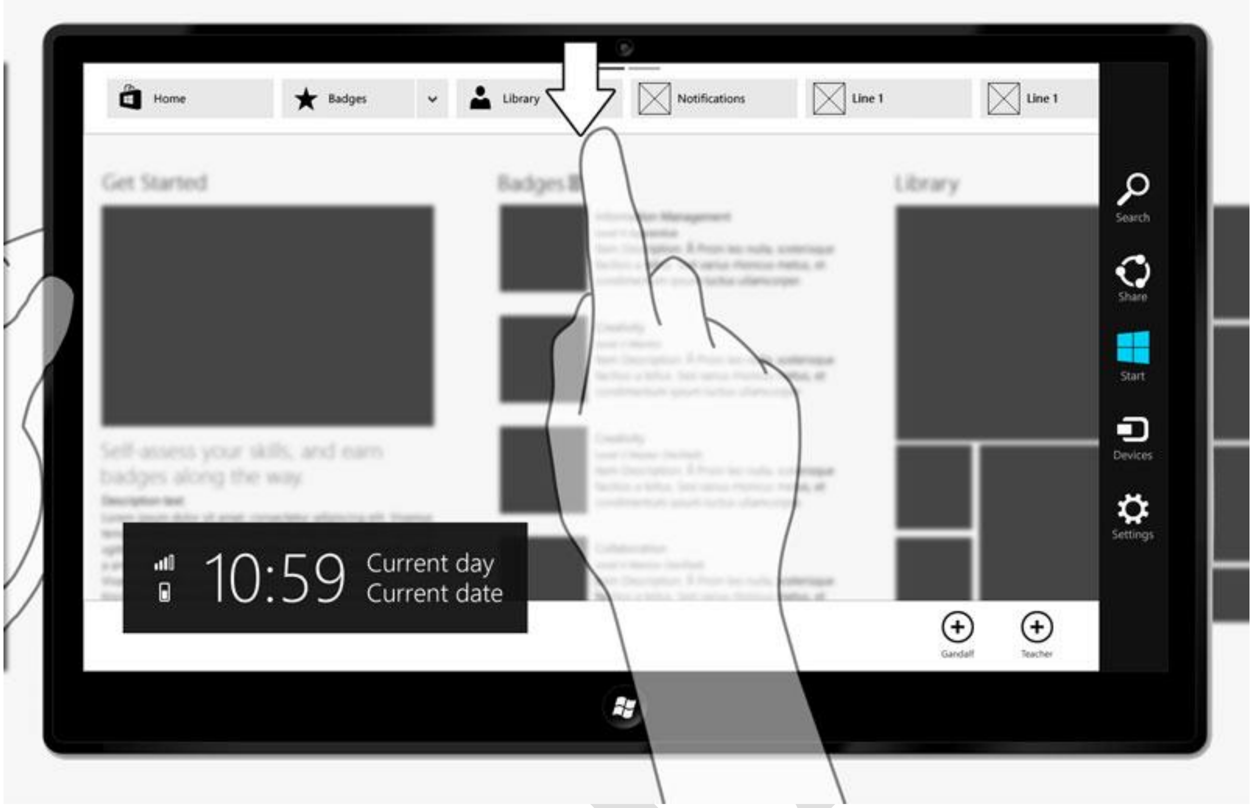


Figure 4. The navigation menu on the Microsoft Surface tablet device. This illustration uses a mockup of the Windows 8.1 operating system. gesture on the bezel of the device, that is a drag down from the bezel into the screen reveals the navigation menu. The low affordance of this menu, the small height of the device's top bezel, and the limited bezel width that is at reach each moment may hinder its use. Right-clicking when using a mouse reproduces the same behaviour.

Specifically, a perception that bad menu design somehow "violates" Fitts' Law seems to be particularly popular. The discussion about how a menu "violates" or "breaks" [*sic*] Fitts' Law is taking place in popular developer blogs and forums, and even in corporate developer forums (in start-ups and multi-nationals alike).

To validate the above, a survey related to Fitts' Law and menu design was designed and circulated to designers and developers.

The survey consisted of a short introduction to Fitts' Law, a question about whether the menu of Figure 4 "violates Fitts' Law" [*sic*], and questions about the occupation of the respondent, their gender, age, and ethnicity. The demographic questions were not asked to validate a pre-existing hypothesis, but rather to allow for better data analysis.

The survey was circulated to various user groups through email and social media (Twitter, and LinkedIn SIGCHI and IxDA Groups).

The next section presents the findings from the CS curriculum analysis and the survey.

4. FINDINGS

4.1 HCI in CS Core Curricula

Out of the 82 analysed CS undergraduate curricula, only 11 (~13%) follow the ACM/IEEE CS 2013 recommendation, and 4 (~5%) other universities offer alternative options that also incorporate HCI in core modules. The 11 universities that include HCI in their Tier 1 employ different methods, ranging from briefly mentioning HCI in their introductory CS courses, to offering obligatory HCI modules. Alternative HCI incorporations include designing UIs at projects, and there is also a singular case where a CS program offers modules from a Design Academy *in its core curriculum*—not as a "dual degree" option (the Hebrew University of Jerusalem offers a CS program with the Bezazel Academy of Art and Design). A list of these institutions is below in Table 1.

Table 1. The 11 top-ranked universities that include HCI as part of their core, Tier 1 CS undergraduate offering (numbered 1 to 11), as well as the 4 universities that offer alternative paths in their CS curriculum that may include some HCI in a core module (a to d).

University	Country	Has HCI in CS Core?
1. Massachusetts Institute of Technology	USA	Yes
2. Nanyang Technological University	Singapore	Yes
3. The Hong Kong University of Science and Technology	Hong Kong (China)	Yes
4. University College London	EU	Yes
5. University of Washington	USA	Yes
6. University of Copenhagen	EU	Yes
7. University of Tokyo	Japan	Yes
8. Australian National University	Australia	Yes
9. University of Queensland	Australia	Yes
10. Yale University	USA	Yes
11. Rice University	USA	Yes, but focuses on Game Design
a. Georgia Institute of Technology	USA	Students can take HCI while on CS 'Thread'
b. Columbia University	USA	Potentially in projects
c. The Ohio State University	USA	Potentially in projects
d. The Hebrew University of Jerusalem	Israel	In CS program with Bezazel Academy of Art and Design

The majority of curricula, that is 42 (~51%) of them, offer HCI as an elective module, and do not mention HCI in their core. However, in all 42 curricula of this kind, it remains unclear why the student is expected to elect HCI as a module: the field is not introduced at any point, and it is unclear what mechanisms are in place to motivate students elect HCI. Thus, students may choose to attend the elective HCI module for pedestrian, rather than academic reasons (e.g., a lecturer of their liking, easier access to previous exams' solutions, or similar).

Other institutions, more specifically 24 universities (~29%), do not include HCI at all in their CS courses, neither mentioned in an "introduction to CS" course nor as an elective course. Moreover, an institution has an HCI course in their course, but it is not offered in 2014-2015 (see Figure 5).

A geographical analysis of the results did not identify specifically interesting patterns. In general, in the USA, Australia, and Europe a variety of offerings has been adopted, while Canadian, Chinese, Korean, and Taiwanese institutions tended to follow one model (offering elective HCI courses, or no HCI at all). However, this difference may have been influenced by the larger sample size for some countries than for others, and should not be considered definite.

In conclusion, approximately 82% of the top-ranked universities do not actively motivate future computer scientists to further explore HCI, and 29% do not even offer basic knowledge about what HCI is. Only 18% of the institutions facilitate an informed choice with regard to studying HCI.

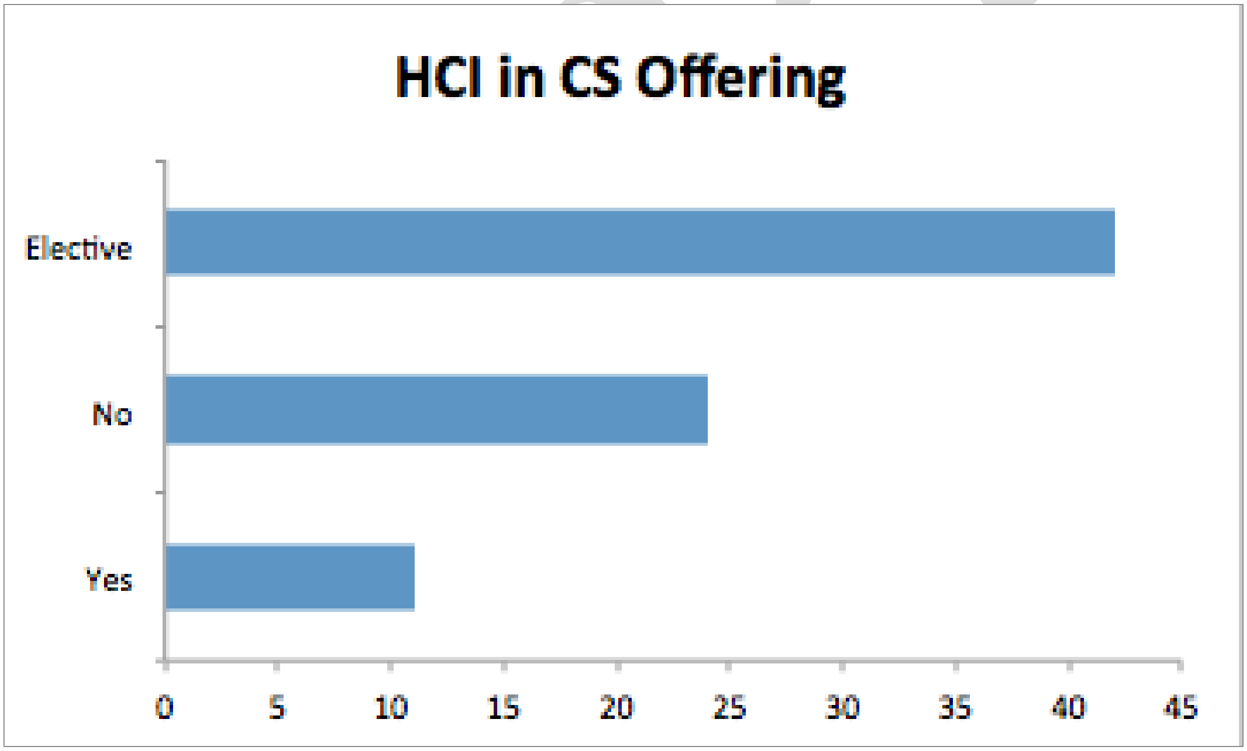


Figure 5. The majority of top-ranked universities do not mention HCI as a field in their core CS undergraduate curriculum.

4.2 Fitts' Law Developers' Perception Survey

Out of the 65 respondents of the survey, 19 (~29%) replied that the menu of Figure 4 "violates" Fitts' Law, and 31 (~47) replied that it does not. 15 respondents (~23%) typed in a response in the "Other" field, of whom only 5 (~8%) respondents questioned the notion of what it means to violate Fitts' Law altogether (Table 2).

Table 2. Demographics for the 5 respondents who questioned the notion of "violating" Fitts' Law altogether.

Respondent	Job Function	Gender	Age	Ethnicity/ies
#16	Designer	Male	45-54	White
#28	Developer	Male	35-44	Prefer not to answer
#57	Researcher	Female	25-34	White
#60	Designer	Male	25-34	Hispanic
#64	Designer	Female	35-44	White

Respondent #64 summarised nicely that: "*I do not know how Fitt's law can be violated if it is a function that returns time*."

Table 3. Number of responses and percentages per group for the survey question based on Figure 4: "In your opinion, does this drag-from-bezel menu violate Fitts' Law?".

Developers		
Answer	**Responses**	**Percentage**
Yes	8	44.45%
No	7	38.89%
Other	3	16.67%
Designers		
Answer	**Responses**	**Percentage**
Yes	4	18.19%
No	12	54.54%
Other	6	27.27%

Respondent #28, the only developer who questioned the "violation" notion, gave a practical example to explain his rationale: "Say Zig's law is, a person who chooses a center seat in a theater walks further than a person who chooses an aisle seat. One person chose an aisle seat. Is Zig's law violated? Absolutely not, a person who chooses a center seat walks further than a person who chooses an aisle seat. The law does not apply to what decisions can or cannot made, it applies to the consequences of those decisions. The particular design decision made by Microsoft does not change the fact that design decisions have consequences, and all Fitt's law states is that design decisions have consequences." The other 3 respondents in Table 2 had a similar line of thought.

Other respondents who typed in the "other" field but didn't question the "violation", perceived Fitts' Law in different ways. A (male, designer, white, 35-44) respondent (falsely) replied that Fitts' Law is only relevant in drag-and-drop operations, and not when reaching a target: "Fits' Kaw is about the target (in this case, where you drop the item) and not about the start location" [*sic*]. A (male, white, 35-44) developer replied that: "because it is an established pattern on mobile i.e. to drag a menu or utility tray from the 'bezel', it works."

In general, developers were more likely to say that the menu "violates" Fitts' Law than designers (Table 3). Moreover, developers were less likely to choose the "other" option and type in their own answer.

With regard to other demographics, there were 12 male and 3 female developer respondents, and 13 male and 8 female designers. Both designers and developers were predominantly white, 11 developers (~69%) and 17 designers (~77%). Designers were slightly older than developers. Moreover, it is worth noting that female respondents were more diverse ethnically, and with regard to age, and predominantly designers (60% designers, 25% researchers, 15% developers). Considering ethnicity, 2 out of 20 non-white respondents (8 Asian/Pacific, 2 Black/African American, 7 Hispanic, 3 preferred not to answer) identified the issue with "violating" the law, while 3 out of 44 white respondents did (10% and 7%, respectively).

5. CONCLUSIONS

In conclusion, when presented with a concrete menu design problem at hand, most designers and developers who participated in the survey (~87%) did not question the premises presented to them. Moreover, only 8% achieved to re-frame the problem in a way that makes sense from an HCI point of view.

At first glance, this seems to be a very limited result about a specific law and how it applies to a particular menu. However, it reveals underpinning misconceptions about what a scientific law is and how it can be violated (e.g., a boat floating on water does not violate the law of gravity).

In addition, 82% of top-ranked universities have not yet adopted the recommendations of (The Joint Task Force on Computing Curricula ACM / IEEE-CS, 2013) to include HCI in their core CS undergraduate curriculum.

The effectively active *epistemological misconceptions about scientific laws* and the lack of computer scientist exposure to HCI may hinder the communication and inhibit the understanding between HCI practitioners or researchers and computer scientists, i.e., the very people who, most of the time, implement the solutions we design.

In the current times when a typical enterprise consists of 15 people (Bureau, U.S. and Statistics, L. 2012), an 8% of people able to re-frame a problem in a scientifically appropriate way would mean approximately 1 person per organisation. Given how group dynamics work, a single person may find it impossible to re-frame a related problem when necessary.

Of course, other factors may also exist, and further research should consider design curricula, life-long learning, and any related non-education factors. Ultimately, this paper is not an attempt to list an exhaustive list of factors, but rather to begin a dialogue which will link HCI Education to actual CS curriculum design.

6. ACKNOWLEDGMENTS

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