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Published in:
Proceedings of the 2020 International Symposium on Wearable Computers

Publication date:
2020

Document Version
Early version, also known as pre-print

Citation for published version (APA):
Genç, Ç., Colley, A., Löchtefeld, M., & Häkkilä, J. (2020). Face Mask Design to Mitigate Facial Expression Occlusion. In *Proceedings of the 2020 International Symposium on Wearable Computers* (pp. 40–44). Association for Computing Machinery. ISWC '20 https://doi.org/10.1145/3410531.3414303

Face Mask Design to Mitigate Facial Expression Occlusion

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Figure 1: The two designs of interactive face mask evaluated in the study. Left: *Mouthy Mask*, Right: *Smiley Mask*

ABSTRACT

The COVID-19 pandemic dictated that wearing face masks during public interactions was the new norm across much of the globe. As the masks naturally occlude part of the wearer's face, the part of communication that occurs through facial expressions is lost, and could reduce acceptance of mask wear. To address the issue, we created 2 face mask prototypes, incorporating simple expressive display elements and evaluated them in a user study. Aiming to explore the potential for low-cost solutions, suitable for large-scale deployment, our concepts utilized bi-state electrochromic displays. One concept *Mouthy Mask* aimed to reproduce the image of the wearer's mouth, whilst the *Smiley Mask* was symbolic in nature. The smart face masks were considered useful in public contexts to support short socially expected rituals. Generally a visualization directly representing the wearer's mouth was preferred to an emoji style visualization. As a contribution, our work presents a stepping stone towards productizable solutions for smart face masks that potentially increase the acceptability of face mask wear in public.

CCS CONCEPTS

• **Human-centered computing → Ubiquitous and mobile computing**; **Interaction paradigms**; **Interaction design**.

ISWC '20, September 12–16, 2020, Virtual Event, Mexico

ACM ISBN 978-1-4503-8077-5/20/09…$15.00
https://doi.org/10.1145/3410531.3414303

KEYWORDS

Face Mask; Electrochromic Display; Wearable Display; Social Acceptance; Covid-19

ACM Reference Format:
Çağlar Genç, Ashley Colley, Markus Löchtefeld, and Jonna Häkkilä. 2020. Face Mask Design to Mitigate Facial Expression Occlusion. In *Proceedings of the 2020 International Symposium on Wearable Computers (ISWC '20), September 12–16, 2020, Virtual Event, Mexico.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3410531.3414303

1 INTRODUCTION

The number of people wearing different face covering items, such as masks or head mounted displays (HMD), is increasing. While HMD use is increasing due the rise of virtual reality (VR), the use of facial masks is now showing a vast increase. Whilst previously face mask use was focused to health care professionals and other professions with high hygiene requirements, the COVID-19 pandemic has seen the emergence of face masks as everyday wear in public interactions. Indeed, during the peaks in the pandemic in some countries, face masks have been a recommended, or even mandatory, accessory. Prior to this, the wearing of face masks in public was a common sight in cities with high pollution levels, but typically the masks were removed during conversations or when indoors. This changed in the pandemic situation, where face masks wear occurred particularly during conversation, and in crowded indoors contexts, such as supermarkets or public transportation. Face masks have become so ubiquitous that they were included as part of outfits at Paris Fashion Week 2020 [12].

While face masks are helpful in protecting us, they cause a remarkable change in peoples' appearance and, consequently, affect our face to face interactions. A face mask hides most of the facial expressions, which are essential in non-verbal communication cues. De Silva et al. [3] have reported that people recognize anger, happiness, surprise and dislike through visual cues, rather than voice. During the COVID-19 pandemic the news media has also identified the potential societal challenges related to the loss of casual smiles in communication, when wearing face masks [17]. Several approached to mitigate this have been proposed, e.g. from the maker community Tyler Glaiel has presented a mask with an LED mouth that animates based on the wearer's speech volume[4] and transparent face masks have been developed [16]. The latter highlighting its benefit for supporting facial identification utilized, e.g., for smartphone unlocking.

We designed, constructed and conducted a user study to evaluate, two smart face masks utilizing electrochromic (EC) display elements. As main findings, the smart face masks, displaying the wearer's occluded smile were considered to be useful in public contexts to support the short socially expected rituals of informal positive social sanctions. Generally, a visualization directly representing the wearer's mouth was preferred to a full face emoji style visualization. As a contribution, our work presents a viable stepping stone towards productizable solutions for smart face masks that potentially increase the acceptability of face mask wear in public.

2 RELATED WORK

In the following we summarize how prior work has explored the problems of facial masking caused by HMDs and face masks, and works that have utilized a face mask for information display.

Whilst face masks restrict the visibility of facial expression by covering the nose and mouth, HMDs do so by covering the eyes, and with the current size of devices, also severely restricting the visibility of the wearer's mouth. Whilst the primary focus of HMDs is to the wearer's experience, they are increasing finding applications and use contexts where the wearer is in the view of other people, to whom the HMD wearer's face not visible. Shwind et al. [15] explored the impact of the HMD in a variety of social settings, reporting that in many settings HMD wear was considered inappropriate. As an approach to mitigate the issues surrounding social HMD wear, Mai et al. [8] presented TransparentHMD, where a display on the outer surface of the HMD renders a 3D model the wearer's face to bystanders, creating the illusion that the HMD is transparent. A similar approach, presenting only animation of the wearer's eyes has been presented by Chan and Minamizawa [1].

Focusing on face masks covering the mouth, Kumazaki et al. [7] developed a face mask display that tracks the wearer's facial expression and presents a photo realistic representation on the outward facing display Focusing to sensing the facial expressions of the wearer, Umezawa et al. [18] developed the e2-Mask, that utilized 40 photo reflective sensors on the face to recreate facial expressions in an avatar. To support telepresence, Misawa and Rekimoto [11] demonstrated the ChameleonMask that displays a remote user's face on the face of a human-surrogate, and concluded that the surrogate is regarded as the actual (remote) person.

As well as facially worn elements such as masks and HMDs, handheld devices such as tablet computers also have the potential to block eye-contact between conversing parties. For example, top address the communication challenges caused by a doctor's face being obscured by a handheld tablet computer during consultation, Colley et al. have presented a dual sided tablet with a supplementary rear facing display [2]. Here, rather than duplicating the doctor's face, conversation supporting media is presented.

The most basic information carried through mask wear, is if the mask is on or off. Schulte et al. [14] present a mask that automatically rises to cover the wearer's face in response to high levels of measured Air Pollution. The authors note that, as the wearer is not in control of the mask's state, it serves as an indicator both to the wearer and those around them. von Radziewsky et al. presented Scarfy, a wearable scarf that detects how it is tied around the wearer's neck and face [19]. For example, in situations when the scarf is configured to cover the mouth, indication of the wearer's state could be sent via social media channels.

Prior works have highlighted both the problems and potential technical solution directions related to loss of facial expressions when the parties in a conversation are wearing face masks. However, the recent COVID-19 pandemic has raised the importance of face mask wear to a new level, and hence justifies revisiting the issue with new criteria. Compared to prior work, we target a solution that is very low cost and supports the general hygiene requirements needed to control the spread of virus. Through this we aim towards solutions that can increase the level of social acceptance for wearing face masks during daily life activities.

3 FACE MASK CONCEPTS

To address the issue of facial expression occlusion during face-to-face social interaction, we developed two smart mask prototypes: *Mouthy Mask* and *Smiley Mask* (Figure 1). The masks were designed to indicate when the wearer smiles, by switching between two visual states. The display elements incorporated into the masks were electrochromic (EC) displays, which are graphical segment-based displays [5] that transition between two predefined visual states when a small voltage is applied. The *Mouthy Mask* involved two stylized states directly representing the wearer's mouth: A straight horizontal line indicating a neutral expression, and an upwardly curved line representing the smiling state. In contrast, in the *Smiley Mask*, the display was based on two emojis : A neutral face illustration with a straight line as a mouth and a smiling face.

Electrochromic displays were selected as they are free-form, giving the opportunity to design the the shape and size of the display elements to integrate to the masks. Further, EC displays are flexible, robust, require very low power for operation and can be manufactured at low cost, making them suitable for the face mask application. The masks were constructed from white cotton fabric, resembling to the face masks commonly worn during COVID-19 pandemic. Both mask styles included 3D printed cases on the mouth area, which, as well as housing the EC display elements, were intended to house sensing electronics and replaceable air filters.

As prior work has already demonstrated methods to sense facial expressions [7, 18], our work focused only on exploring the the display side of the interaction, and hence relied on manual switching of the display state by the wearer, via a wired switch. This approach was suitable for our chosen Wizard of Oz evaluation method [9], where the face masks were worn by the test moderator.

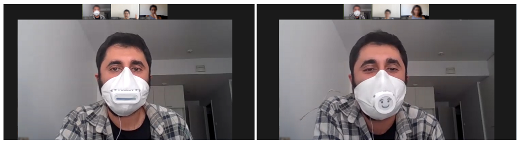

Figure 2: Screenshots of the user study participant's view of the test moderator

4 USER STUDY

To understand our prototype face masks' influence on social interaction and potential users' perception on their social acceptability, we conducted a user study with 12 participants.

4.1 Method

Due to the limitations imposed during the COVID-19 pandemic, the study was conducted online via the Zoom video conferencing tool (Figure 2) and involved one of authors as the test moderator having casual conversations with the study participants while wearing the two smart mask prototypes and a regular face mask as a control condition. The study was conducted using the Wizard of Oz approach [9], where the moderator manually controlled the state of the masks during conversations, using a handheld switch.

After completing a consent form, the aim of the study was introduced as receiving user feedback on the design of smart masks for expressing facial expressions. Then, the topics for the conversation sessions were roughly defined together with participants, i.e. "places to visit", "movies to watch" and "life during quarantine". During the conversation sessions, the participants were asked to pin the view of the moderator in the Zoom interface to ensure they observed the masks clearly (see Figure 2).

The study consisted of 3 conversation sessions, each lasting 5 minutes, in which the moderator wore one of the smart face masks or a regular. The presentation order was counterbalanced among participants. After each session, participants rated a set of statements on the influence of the masks to social interaction and social acceptability on a 5-point rating scale. The statements about the social interaction were adapted from prior works on the effect of wearable displays on face to face conversation [10] and included seven statements about the masks' influence on attention and concentration, on natural behavior and on understandability of the emotional state of the wearer. The social acceptability questions asked participants to rate the acceptability in different locations (home, sidewalk, public transportation, pub or restaurant, shops, workplace) and with different audiences (partner, friends, family, colleagues, strangers). The options for the contexts and audiences were derived from prior works on social acceptability in HCI [6, 13].

Following the conversation sessions, a semi-structured interview was conducted to collect qualitative feedback on the prototype face masks from the participants. Ten participants attended the study in pairs, whilst two others were individual sessions. Each study lasted approximately one hour and was video recorded for later analysis.

4.2 Participants

We recruited 12 volunteers for the study, six males and six females, aged between 25 and 36. Seven of the participants already knew the test moderator. All the participants were living in Turkey during the CORONA-19 outbreak, with one exception who was situated in Denmark. All participants had some practical experience of wearing a face masks in the presence of other people.

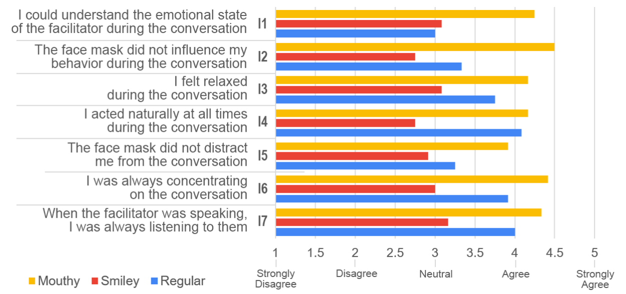

Figure 3: Mean values of the subjective ratings for the masks' influence on social interaction

Table 1: Significant (p<0.05) differences in ratings for the masks' influences on the social interaction (Wilcoxon signed-rank). M=Mouthy, S=Smiley, R= Regular mask.

	R-S	M-R	M-S
Item1		M>R p=0.0	M>S, p=0.014
I2		M>R p=0.016	M>S, p=0.007
I3	R>S, p=0.004		M>S, p=0.012
I4			M>S, p=0.025
I5			M>S, p=0.05
I6	R>S, p=0.02		M>S, p=0.01
I7			M>S, p=0.02

4.3 Results

Overall, participants were positive about the idea of having a facial expression display on the masks, e.g. *"The regular masks are limiting for social interaction in terms of conveying emotions. Therefore, I liked the function of the masks"* (P3). However, participants also expressed some concerns about the smart face masks. In the following, we detail the positive and negative aspects of the facial expression masks by referring to the study results.

4.3.1 Influence on Social Interaction. Figure 3 summarizes the subjective ratings on the influence of the masks during social interaction. Statistical analysis was made using the Friedman test with post-hoc pair-wise Wilcoxon signed-rank tests (Table 1). The results regarding attention and concentration (Items 5-7) revealed significant differences among test conditions: The *Mouthy Mask* was rated significantly less distractive than the *Smiley Mask*. The ratings for I6 also suggest that people might have trouble focusing on the conversation when the partner wears the *Smiley Mask* compared to wearing a regular mask. In addition, the participants rated relaxation status with the *Smiley Mask* significantly less than a regular mask and the *Mouthy Mask* (I3). Also, when compared to the *Smiley Mask*, the *Mouthy Mask* was rated significantly better in conveying the emotional state (I1) without influencing the natural behaviors of the participants during conversations (I2-I4).

During the semi-structured interviews, the reasons for the *Mouthy Mask* being less distractive was opined as its ability to blend with

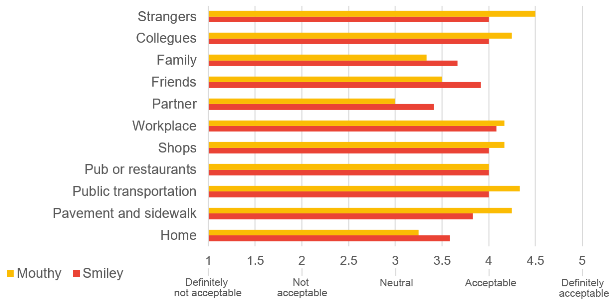

Figure 4: Mean values of the subjective ratings of the social acceptability for different locations and audiences

the face, such that that the display state change was on the periphery of vision while eye contact was maintained (stated by 8/12 participants), commenting, e.g., *"The Mouthy was more complementary in a sense that I can keep my focus on the eyes"* (Participant 6). On the other hand, the small display of the Smiley mask with too many details was hard for some participants (2/12) to follow. In addition, it was noted seeing an emoji felt like a weird 'second face' on the wearer's mouth area which contributed to the distraction while in conversation (2/12).

4.3.2 Long vs. Short Social Interactions. When asked about the best conditions to wear the smart mask prototypes, most of the participants (9/12) considered that the smart masks indicating smile would be more useful during short social interactions such as greeting or smiling at others as a gesture in public places (e.g. supermarkets, on the street or public transportation): *"When I see a fellow doctor on the corridor, I smile. Before Corona, we greeted each other that way. But now, I smile but they don't see it"* (P8). Another highlighted *"If a waiter, cashier or salesperson smiles, it gives you the feeling that you are well treated. It might be useful in those conditions. This applies for most of the sectors in service provision"* (P5). The facial expression masks might also be useful for preventing misunderstandings with strangers: *"Yesterday, a member of staff at pharmacy warned me about not crossing a line. I smiled instinctively. But the person saw me only looking at him. He thought I was angry with him"* (P4). In the other contexts the smart masks were noted as being a fun artifact at friends gatherings and a conversation starter,i.e. in pubs.

On the other hand, during the long conversations with others, the masks with just two expressive states were considered inadequate (7/12): *"For instance, when you get upset your facial expressions might change in a subtle way. When you have only two states, the subtlety of such expressions diminishes. It becomes unnatural"* (P4). Also, the participants – both the ones who already knew the moderator and the ones who just met him – reflected on the conversation sessions and noted that, in most of the cases, the emotional state of the wearer was easily understood from eye gestures and tone of voice (9/12). For them, smart masks became *"not that necessary"* (P2) in longer social interactions.

4.3.3 Social Acceptability. All the participants indicated that they wouldn't have problems wearing the smart masks in some social settings. Although the mean ratings are on the positive side for all locations and audiences (Figure 4), the results suggest that wearing the smart masks with strangers and coworkers was considered more suitable than with family, friends and partners at home. One of the participants motivated this by saying *"you take them (friends and families) within the boundaries and take the time you spent with them for relaxing... It's not that I would be ashamed but a bit over cautious"* (P7). Another reason was *"I would understand the people I know from the eyes and the tone"* (P10).

The social acceptability ratings also indicated a slight difference between the *Smiley* and the *Mouthy* masks: the former was less preferred with strangers and coworkers when compared to the *Mouthy*, whereas the situation was reversed with friends, families and partners. The reason was explained by one participant's feedback: *"Smiley was more sympathetic"*. Another commented *"When I am talking with a customer, I would require them to take me seriously."*. Aligned with those, wearing a mask that indicates the wearer is smiling in serious contexts raised some concerns among participants: *"if I wear it in a court it would be weird"* (P9). To cope with that, one participant suggested, *"It would be more comfortable if I activate it whenever I want"*.

5 DISCUSSION & CONCLUSION

Utilising electrochromic (EC) display technology we were able to design and construct smart face masks that present a believable step towards a productizable solution. Whilst we did not explore mechanisms to control the display switching we believe that straightforward solutions can be found based on simplified versions of prior work on the topic [7, 18]. Our approach of evaluating the face masks over a video conversation was mandated by the social isolation rules in operation at the time of the study. However, we consider the approach we developed worked well and delivered findings that are also applicable to physically co-located face-to-face conversations.

We acknowledge that the generalizability of our findings is limited by our sample size (n = 12) and limited cultural diversity of our study participant sample. We note the general agreement between our test participants' opinions on our mask prototypes and use context and believe our dataset is approaching saturation. Whilst some social interaction gestures require cultural interpretation, the focus of our work, the smile, is universally understood.

Smart face masks, including a display presenting the wearer's occluded smile were considered to be useful in public contexts to supporting the socially expected rituals of informal positive social sanctions. In such short interactions the presentation of 2 states, neutral and smiling was considered adequate. For longer conversations and when conversing with close family and friends, the masks were not considered useful. Generally a visualization directly representing the wearer's mouth was preferred to a full face emoji style visualization.

As future work, we plan to extend our implementation to incorporate a mechanism to automatically switch the face mask display state and evaluate its use in the wild. Of particular interest is the tolerance for false positives, i.e. smiling when it is not intended.

ACKNOWLEDGMENTS

This work was funded by EU project DecoChrom, grant no. 760973 of European Union's Horizon 2020 research and innovation programme, and the Academy of Finland as part of the TechFashion - Design of Future Wearable Computing project.

REFERENCES

[1] Liwei Chan and Kouta Minamizawa. 2017. FrontFace: Facilitating Communication between HMD Users and Outsiders Using Front-Facing-Screen HMDs. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services* (Vienna, Austria) *(MobileHCI '17)*. Association for Computing Machinery, New York, NY, USA, Article 22, 5 pages. https://doi.org/10.1145/3098279.3098548

[2] Ashley Colley, Juho Rantakari, Lasse Virtanen, and Jonna Häkkilä. 2017. Mediating Interaction Between Healthcare Professionals and Patients with a Dual-Sided Tablet. In *IFIP Conference on Human-Computer Interaction*. Springer, 54–61.

[3] Liyanage C De Silva, Tsutomu Miyasato, and Ryohei Nakatsu. 1997. Facial emotion recognition using multi-modal information. In *Proceedings of ICICS, 1997 International Conference on Information, Communications and Signal Processing. Theme: Trends in Information Systems Engineering and Wireless Multimedia Communications (Cat.*, Vol. 1. IEEE, 397–401.

[4] Tyler Glaiel. 25th May 2020. Talking face mask. https://twitter.com/TylerGlaiel/status/1257564002193833985. Accessed: 23rd June 2020.

[5] Walther Jensen, Ashley Colley, Jonna Häkkilä, Carlos Pinheiro, and Markus Löchtefeld. 2019. TransPrint: A Method for Fabricating Flexible Transparent Free-Form Displays. *Advances in Human-Computer Interaction* 2019 (2019).

[6] Marion Koelle, Swamy Ananthanarayan, and Susanne Boll. 2020. Social Acceptability in HCI: A Survey of Methods, Measures, and Design Strategies. (2020), 1–19. https://doi.org/10.1145/3313831.3376162

[7] Ryoga Kumazaki and Akifumi Inoue. 2019. Development and Evaluation of a Mask-Type Display Transforming the Wearer's Impression. In *Proceedings of the 31st Australian Conference on Human-Computer-Interaction* (Fremantle, WA, Australia) *(OZCHI'19)*. Association for Computing Machinery, New York, NY, USA, 568–571. https://doi.org/10.1145/3369457.3369533

[8] Christian Mai, Lukas Rambold, and Mohamed Khamis. 2017. TransparentHMD: Revealing the HMD User's Face to Bystanders. In *Proceedings of the 16th International Conference on Mobile and Ubiquitous Multimedia* (Stuttgart, Germany) *(MUM '17)*. Association for Computing Machinery, New York, NY, USA, 515–520. https://doi.org/10.1145/3152832.3157813

[9] David Maulsby, David Maulsby, Saul Greenberg, Richard Mander, and Mariani Ave. 1993. Wizard of Oz Prototyping an Intelligent Agent through Wizard of Oz. (1993).

[10] Gerard Mcatamney, St Vincent Street, and G Uk. 2006. An Examination of the Effects of a Wearable Display on Informal Face-To-Face Communication. (2006), 45–54.

[11] Kana Misawa and Jun Rekimoto. 2015. Wearing Another's Personality: A Human-Surrogate System with a Telepresence Face. In *Proceedings of the 2015 ACM International Symposium on Wearable Computers* (Osaka, Japan) *(ISWC '15)*. Association for Computing Machinery, New York, NY, USA, 125–132. https://doi.org/10.1145/2802083.2808392

[12] Hollywood reporter. 27th February 2020. Fashion brand debuts face masks at paris fashion week. https://www.hollywoodreporter.com/news/fashion-brand-debuts-face-masks-at-paris-fashion-week-coronavirus-1281590. Accessed: 14th May 2020.

[13] Julie Rico and Stephen Brewster. 2010. Usable Gestures for Mobile Interfaces : Evaluating Social Acceptability. (2010), 887–896. https://doi.org/10.1145/1753326.1753458

[14] Britta F. Schulte, Zuzanna Lechelt, and Aneesha Singh. 2018. Giving up Control - A Speculative Air Pollution Mask to Reflect on Autonomy and Technology Design. In *Proceedings of the 2018 ACM Conference Companion Publication on Designing Interactive Systems* (Hong Kong, China) *(DIS '18 Companion)*. Association for Computing Machinery, New York, NY, USA, 177–181. https://doi.org/10.1145/3197391.3205432

[15] Valentin Schwind, Jens Reinhardt, Rufat Rzayev, Niels Henze, and Katrin Wolf. 2018. Virtual Reality on the Go? A Study on Social Acceptance of VR Glasses. In *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct* (Barcelona, Spain) *(MobileHCI '18)*. Association for Computing Machinery, New York, NY, USA, 111–118. https://doi.org/10.1145/3236112.3236127

[16] TechTimes.com. 26th June 2020. FDA approved transparent face mask. https://www.techtimes.com/articles/250624/20200626/covid-19-update-first-fda-approved-transparent-n99-mask-with-uv-c-sterilizing-now-available.htm. Accessed: 26rd June 2020.

[17] New York Times. 23rd June 2020. Masks Keep Us Safe. They Also Hide Our Smiles. https://www.nytimes.com/2020/06/23/style/face-mask-emotion-coronavirus.html. Accessed: 23rd June 2020.

[18] Akino Umezawa, Yoshinari Takegawa, and Keiji Hirtata. 2017. e2-Mask: Design and Implementation of a Mask-Type Display to Support Face-to-Face Communication. In *International Conference on Entertainment Computing*. Springer, 88–93.

[19] Luisa von Radziewsky, Antonio Krüger, and Markus Löchtefeld. 2015. Scarfy: Augmenting Human Fashion Behaviour with Self-Actuated Clothes. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction* (Stanford, California, USA) *(TEI '15)*. Association for Computing Machinery, New York, NY, USA, 313–316. https://doi.org/10.1145/2677199.2680568