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A positive image would inspire the capable but underrepresented who might otherwise give up on computing.

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Countering the Negative Image of Women in Computing

DESPITE INCREASED KNOWLEDGE about gender (in) equality,[7,27,38] women in STEM disciplines are still portrayed in stereotypical ways in the popular media. We have reviewed academic research, along with mainstream media quotes and images for depictions of women in STEM and women in computing/IT. We found their personality and identity formation continues to be influenced by the personas and stereotypes associated with role images seen in the media. This, in turn, can affect women's underrepresentation and career participation, as well as prospects for advancement in computing fields.

The computer science Degree Hub[15] in 2014 published its list of the 30 most influential, living computer scientists, weighing leadership, applicability, awards, and recognition as selection criteria. The list included only one female, Sophie Wilson, a British computer scientist best known for designing the Acorn Micro-Computer, the first computer sold by Acorn Computers Ltd. in 1978. A fellow elected to the prestigious Royal Society, Wilson is today the Director of IC Design at Broadcom Inc. in Cambridge, U.K., listed as number 30 of the 30 on the list.

Several other observations are notable about the list. The other 29 are all male, with one from Mexico—Miguel de Icaza—and one from Japan—Yukihiro Matsumoto. In general, 15 of the 30 at the time worked in industry, at major tech organizations, including Dropbox, Facebook, Microsoft, PayPal, and Google. Others were academic scholars, along with several entrepreneurs. However, women tend to seek alternatives to traditional computing/IT industry and academic careers by establishing IT-related or entrepreneurial venues.[38,40] Nonetheless, the fact remains that with only one female on the list and one male from a traditionally underrepresented majority minority country does communicate as to who influences, controls, and ultimately is expected to participate in computing. Computing awards and recognitions often seem to derive from the well-recognized relationship between masculinity and technology, particularly in terms of what are considered technical skills and masculine identity.[2,7] Such acknowledgments in the media often function as an unofficial recruitment policy, influencing academic and career choices.

» key insights

- **The lack of sustained gender and ethnic participation persists in computing.**
- **Media images produce mental models of who participates and what participation even looks like.**
- **One common image is that men can be ordinary while women must be exceptional, and women of color must be better than exceptional.**

IMAGE BY YANAWUT SUNTORNKIJ

Recent popular media attention has begun to focus on the lack of gender and ethnic diversity in Silicon Valley. The experience of women in these settings was documented by Mundy[28] and is available in the online appendix "Media Representations of Women in Computing Through Text and Images" (dl.acm.org/citation.cfm?doid=3319422&picked=formats).

Mundy[28] pointed out that tech companies have spent millions of dollars to recruit and improve the workplace environment and conditions only to find little has changed for women in tech, even today. Mundy[28] reflected on women and ethnic minorities abandoning tech careers, misogynistic and "bro" culture, hostile workplace conditions, lack of access to leadership roles, and biases as barriers to inclusion.[4,39]

The Valley is home to Facebook, Google, Apple, Yahoo, LinkedIn, Twitter, and many other organizations that recruit from the talent pool of undergraduate students in nearby universities who earn degrees in information systems/sciences and computer science. Relevant to the talent-pool recruitment policies and results is the data reported by the National Science Foundation,[29] showing several professional trends:

Black and Latina women. Black and Latina women combined (in 2016) earned only 4.4% of all undergraduate computing degrees in the U.S.; women overall earned 28.5%, 25.1%, and 18.1% of all bachelor-level computer science degrees in 1995, 2004, and 2014, respectively. Computer science was termed a "low participation" field for these underrepresented minorities while Latina women's completion of undergraduate computer science degrees in the U.S. was flat between 1995 (1.75%) and 2014 (1.79%). For black women, these numbers were 5.10% and 2.61%, respectively.

For 2012, the National Science Foundation reported 70% of all black computing degree earners were male, and 81% of Latino computer science degree earners were male. Within the tech workforce, 25% of all computing professionals were female, with only 4% of them African American (3%) or Latina (1%).

Similar numbers were reported by The Chartered Institute of the U.K. in its 2014 *Women in IT Scorecard*.[10] Of the 753,000 people working in the IT sector at the time, only 20% were women. In 2013, 11% of IT specialists were women. Women were much more likely to hold technician/engineer-grade positions than men (34% vs. 20%, respectively)[10] and less likely to be working in "professional," or primarily development-related, occupations (46% vs. 57%).

As early as the 1980s, barriers to work participation for women and underrepresented minorities in science, along with the need for intervention programs and strategies for increasing participation, were being documented;[21] for example, an earlier (1978) observation by Austing et al.[5] about the dearth of women and underrepresented minority computer science faculty were documented in *Communications*.[5] Yet, a comparison of 2014 statistics and facts[29] reported a downward trend for participation by female and underrepresented groups in computing/IT careers despite the counternarratives of these statistics from the 1960s to the early 1980s. Abbate[1] documented the history of computer science in 2012, noting that programming was seen as "women's work" in the years following World War II. The media and entertainment industries have taken note of women programmers' achievements (in such movies as *Ghostbusters*, *Hunger Games*, and even *Star Trek*) despite common stereotypes and other obstacles that largely ignored black women in the narrative, until the 2016 release of *Hidden Figures*. Moreover, the image of the computer geek emerged in the 1980s with depictions of "hackers" and "nerds" in the mass media, depicting these characteristics as masculine.

Sociocultural Gender Barriers

Stereotyping refers to the attributes the general public thinks characterize a particular group. Studies of systemic stereotyping dimensions refer to traditional content of what people in a society think of others and try to reveal the systemic (holistic) reasons and mechanisms involved in stereotyping. Researchers, including Fiske et al.,[14] categorized four types of stereotypes and their systemic dimensions resulting from feature combinations of perceived warmth and competence, as outlined in the figure here.

Accordingly, social status[14] predicts competence, and competition yields only modest warmth. Some stereotyped groups (such as the elderly) are depicted as being unable and useless, whereas others (such as Asians) are respected for their excessive, yet potentially threatening, dedicated competence. These pairings can also affect how women view themselves and how the broader culture perceives gender status and competence, as well as computing skills and capabilities.

Fiske et al.'s classification of status[14] is not without some qualification. Even Hofstede's classification[20] needs to be reconsidered and enriched[33] to acknowledge that stereotypes are distinguished by national and broader social

Societal stereotypes.

Warmth	Competence: Low	Competence: High
High	**Paternalistic stereotype** low status, not competitive (such as housewives, elderly people, and disabled people)	**Admiration** high status, not competitive (such as the in-group and close allies)
Low	**Contemptuous stereotype** low status, competitive (such as welfare recipients, poor people)	**Envious stereotype** high status, competitive (such as Asians, Jewish people, rich people, feminists)

culture, considering several persistent geopolitical factors:

Power distance. The extent hierarchies and unequal power distribution are accepted;

Uncertainty avoidance. The extent a society feels threatened by ambiguous situations and tries to avoid them by establishing rules, believing in absolute truths, and refusing to tolerate deviance;

Masculinity vs. femininity. The relationships among masculine assertiveness, competitiveness, and materialism as opposed to the feminine concern for quality of relationships, nurturing, and social well-being; and

Individualism vs. collectivism. The relationship between individual independence and the group's collective interdependence.

Other researchers, including Cheryan et al.,[12] have examined the stereotypes of professionals in computing to determine if changing them can affect women's interest in the field. Cheryan et al.[12] reported computer scientists are conventionally viewed as introverted, narrowly focused, and "non-feminine." However, when these stereotypes were dispelled by exposing young women in the study to media representations of non-stereotypical female computer scientists, they expressed more interest in computing. Cheryan et al.[12] concluded stereotypes about certain academic disciplines can influence who chooses to enter them, and intentional media messages that dispel the stereotypes can help attract more women into the field.

Women themselves can promote female stereotypes in tech and exhibit biases that produce self-defeating normalized thinking. Researchers, including Thornham and MacFarlane,[36] have described how teenage and adult women portray themselves in a "habitual feminine position of incompetence" regarding tech. Women participating in such surveys often evoke a more-traditional and less-progressive view of femininity and thereby restrict their own performance. Women in these instances use their gender as a tool to distance themselves from tech and demonstrate disinterest.[36] Gender stereotyping exposures should thus be addressed much earlier and more broadly in the lives of female students in light of the education and media images that inform and influence mental models held by all, regardless of gender.

IMAGE BY JACOB LUND

The influence of stereotypes is not limited to women in computing but can affect women in leadership roles as well. Researchers, including Simon and Hoyt,[34] conducted two experimental studies in 2012 to understand how media images that portray women in non-stereotypical roles can influence women's gender-role mind-sets, finding women who see media images of females in non-stereotypical roles subsequently reported less negative self-perception, greater leadership aspiration, and stronger belief that women can take on nontraditional gender roles.[34] Such attitudes have powerful implications for the role media, both on- and offline, can play in promoting gender participation and broadening participation efforts, as well as women taking on leadership roles in the field.

Stereotyping in Computing and IT

Because our research motivation is to explicate and report role stereotyping phenomena beyond statistical data, we consider aspects of how gender is depicted in the media. To explore biases in the field of computing, it is useful to start with the connection between masculinity and technology. The connection is not inherent in gender differences but rather a result from the historical and sociocultural construction of gender.[12] We thus elaborate on the background that is necessary to understand this perspective through media sources.

We used three such sources to explore the role of images of women in computing: interviews from the *Huffington Post*,[17] stories on National Public Radio (NPR),[35] and reports from the U.K. Women in Tech Council.[9,10,38] They provide publicly available evidence to assess how women are depicted in computing, as selected by us based on their reporting of women in computing, as well as their broad media reach and engagement. In 2012, the *Huffington Post* website had 84 million unique visitors worldwide,[17] and NPR had 25.6 million unique monthly listeners through more than 1,000 public U.S. radio stations.[35] The U.K. Women in Tech Council is a member organization consisting of 850 companies that collectively employ more than 700,000 professionals in the U.K. and focus on issues of gender and leadership in the technology sector.[38]

Females, computing, and image interpretation. Research studies, including by Gioia et al.,[18] provided guidance for determining qualitative rigor in the inductive research we report here. Researchers, including Gioia et al.,[18] demonstrate how first-order concepts in qualitative data appear to fly off in all directions and even become unmanageable. Second-order themes can then follow and explain the phenomena (such as images of women in computing) under investigation. Lastly, the aggregated dimensions can be presented as a visual representation to show a progression from raw data to higher-order themes, including bias, stereotypes, and "intersectionality."

We sought out and identified in-

sightful quotes from the following media posts under the following headlines:

"Is The Stereotype That 'Women Can't Be Geniuses' Causing Gender Gaps?" (*Huffington Post*, 2015);[17]

"The Forgotten Female Programmers Who Created Modern Tech" (National Public Radio blog, 2014);[35] and

"The U.K. Women in Tech Council (British Computing Society–Women in IT Interviews)" (2014).[38]

Media posts and projected images. To help comprehend the theoretical analysis of the role of cultural stereotypes, as outlined earlier, we include the media-source quotes and relevant second-order themes in a table in the online appendix while offering images of women online in IT and computing, along with qualitative rigor.[18] Text analyses with second-order themes, including media/tech acculturation, entrepreneurship alternatives, shifts in role/identity work, and the intersectionality associated with women of color, at the intersection of race and gender. These second-order themes map to the literature related to gender and tech.

The table in the online appendix outlines the themes and clichés concerning women in tech that are dominant in the mainstream media and fall into three categories: extraordinary achievement; intellectual differences; and hypermasculinity in traditional old-boys-club personas. The following section relates these themes to challenging theories concerning women's historical underrepresentation and participation in computing/IT.

The Media and Underrepresentation

Beyond media posts and raw data in the table in the online appendix, the research literature also provides evidence of stereotypical images associated with women and underrepresented minorities in computing and IT. The following research demonstrates the exceptional or extraordinary depictions of intellectual differences and hypermasculine descriptions we found in scholarly works, even in the most current literature.

A 2010 study of 86 male and female scientists in the U.K. found women in computing are portrayed in ways that overemphasize their appearance and sexuality. Men and women are not represented equitably, with women often portrayed as "exceptional," implying female participation in computing means being uniquely incomparable and to some degree abnormal and a transgression in the male-dominated culture of work. "Ordinary women" are perceived as less than capable, while ordinary men can and do fully participate in the computing disciplines. Additionally, when the media (re)presents women, it is done to "sex up" technology to increase the popularity of the field,[13,16] with minimal focus on intellectual aptitude,[28] as in the images in the online appendix.

These gender-clichéd images and media text references continue to be portrayed online by Web authors despite designers and developers having progressive, non-stereotypical views of the roles of women in tech. For example, Mendick and Moreau[27] found this happens when Web authors work within a constrained journalistic or scientific culture that lacks gender equity. Web authors (or designers) thus frame and articulate Web content within these confines of gender-imbalance, even though they do not endorse the gender stereotypes themselves.[7,27] Regarding race and ethnicity, Payton[31] explored the importance of co-creation of online content to reach typically overlooked and underrepresented groups, highlighting the need to amplify dampened voices, as well as self-creation in content development. While the context of such content related to dissemination of health care, black women engaged more with an online platform designed by and for black women, and when a degree of co-ownership and agency inspired positive (uplifting) imagery, nonbiased messaging, and active user participation.[31]

IMAGE BY FRAME STOCK FOOTAGES

Gender-clichéd images and gender symbolism. The online appendix includes examples of historical stereotypes that have been commercially available for some time, influencing the perceptions of men and women alike. Our research found masculinity and femininity are often used when the description of someone's behavior and skills is highlighted and interpreted through a gender-symbolic lens. Gender symbolism can be seen in the connection between, say, masculinity and tech;[37] it does not explicitly state that technology reflects the capacities of specific (real) men but more likely hegemonic masculinity,[23,25] or traditions and attitudes (such as stereotypes) that legitimize the male-dominant position in society, thus reinforcing gender inequality. Hegemonic masculinity is reflected in ordinary human behavior. For example, some researchers considering gender and computing and IT2[12,25] have recently acknowledged that when publishing descriptions of men with computers, the frame of reference included engagement of superior knowledge and intellectual capacity, as well as technological mastery and power that may strengthen a man's masculine self-image, whereas women with computing skills were mostly associated with typewriting, calculators, and office work, as in the online appendix. As concluded by some researchers, including Bhatt et al.,[7] gendered stereotypes not only influence perceptions of "associated type of work" but also who is able to even participate in computing.

Media portrayals of people, male and female alike, in science and math tend to create and support specific, gendered stereotypes about what a scientist is supposed to "look like." These stereotypes can significantly influence young women's decisions to pursue STEM subjects in school and later professionally. Here, we consider two prevalent stereotypes in media: women are inherently worse at science and math than men, and being a scientist involves character traits like being asocial that are inherently unappealing to young women.[7]

Gender and race in media stereotypes. With regard to race and participation in computing, Nelson[30] provided an intensive examination of the scholarly literature, concluding researchers often ignore mainstream publications to gain a richer historical perspective of the field. For example, Nelson[30] referenced *Ebony Magazine* in a study of race and gender using "prosopography," or a description of a person's appearance, personality, and career. Considered a nontraditional source, *Ebony Magazine* can provide insights into how people view themselves and others. Nelson[30] documented at least 57 black professionals in computing from 1959 to 1996.[30] *Ebony Magazine* was founded in 1945 by black entrepreneur John H. Johnson and is a leading mainstream black publication covering how politics, science, business, the arts, and education affect the black community in the U.S. and globally.

"Ordinary women" are perceived as less than capable, while ordinary men can and do fully engage and participate in the computing disciplines.

There is also the issue of intersectionality of gender and race as generally experienced by women of color. For women of color in tech, the double-bind obstacles remain, even after the groundbreaking 1976 study by Shirly Malcom and Lindsey Malcom in the *Harvard Educational Review* as analyzed years later in "The Double Bind: The Price of Being a Minority Woman in Science."[26] The image and degree-attainment issues were and continue to be even more visible at the doctorate level, as reflected in the following quote from a related 2011 AAAS press release:[26] "They have made broad gains in social and behavior sciences, but lack badly in other fields. In computer science, for example, 2.1% of 2008 Ph.D.'s went to minority women scientists—just 14 women in all. While records show that no women received engineering Ph.D.'s in 1975, the number in 2008 had risen only to 91, or 2.9% of the total."

In the 2016 report *Barriers and Bias: The Status of Women in Leadership*, the American Association of University Women[3] further underscored the effects of an intersectional context, indicating that black, Hispanic, and Asian women are often subjected to stereotypes and unconscious bias more widely than their white counterparts.[3] These effects are similar and do not vary widely from corporate, nonprofit, govern-

A scene from a recent CS summer research group at Harvey Mudd College, Claremont, CA, where female participants outnumbered the males.

ment, and academic environments. It also discussed the effects of limited role models, even as it countered negative, often stereotypical, images in the mass media.[34] Given the lack of representation of women of color in computing, as outlined earlier and in the double-bind framework,[26] our understanding of media images is vital for men and women alike to better appreciate how the field has and has not progressed in terms of inclusive representation and participation while embracing leadership and entrepreneurial pathways.

Despite this call for inclusive participation and a longstanding invisibility prism associated with women of color, some researchers, including Blickenstaff,[8] have described the prism as a lack of opportunity as seen through the lens of a leaky pipeline or alternatively gendered filter.[8] When considering gender, race, and other factors affecting career selection and participation, we should also embrace efforts to broaden participation in media messaging with "intentionality." Intersectional perspectives[24] are central to augmenting identity work frameworks of women in computing. The matter of ordinary males and exceptional females raises a new challenge: minority women have an even greater challenge, along with the one self-imposed and/or reinforced by computing culture—to be significantly better than their peers. This notion raises the question: How can minority women be better than exceptional?

Underrepresented professionals and turnover due to unfair treatment. Gender stereotyping can contribute to women's and underrepresented minorities' lack of participation in computing and IT, reflecting discriminatory treatment, as well as being detrimental to innovation, creativity, and personal motivation.

Besides being pushed out or voluntarily leaving the field, U.S. women leave computing and IT at a rate 45% higher than their male counterparts. For example, in 2014 and 2017, women in Brazil, China, India, and the U.K. reported they would quit within a year ranged from 20% to 30%.[11,15] In a representative sample of U.S. adults who left an IT job between 2015 and 2017, a Kapor Center for Social Impact and Harris Poll study reported unfair treatment cost the U.S. tech sector $16 billion annually, concluding: "Unfair treatment is the single largest driver of turnover affecting all groups, and most acutely affects underrepresented professionals."[22]

Bro culture, stereotypes, family issues, working conditions, organizational climate, and lack of sponsors and allies were, along with outright personal bias, were identified as barriers to navigating careers in computing and IT, according to the Center for Talent Innovation, 2014,[11] and other sources.[7,24,32,39] Despite such social and structural issues facing women and underrepresented groups in computing and IT,[32] some historically underrepresented groups are finding entrepreneurship to be a promising alternative career path. *The State of Women-Owned Businesses American Express 2016 Report* stated there were 11.3 million women-owned businesses in the U.S. as of 2016, a 45% increase over 2007. These figures also reflected the growth of female entrepreneurship in Europe, as of 2016.[40]

Conclusion

We observed popular media images and references to women in computing and IT focusing on the "likeness" of how much women exhibit and reflect masculinity and asocial features. These limited perceptions of women (of themselves and/or by others) have been found to influence women's personal decisions about educational and professional life, including matriculation, research priorities, and career trajectories. Educational institutions and industry will continue to experience participation fractures within historically underrepresented gender and ethnic groups. Biased images and perceptions of who participates and ultimately succeeds in computing will continue to be constrained by an often-biased worldview. We analyzed facts and preconceptions in order to provide a more realistic understanding and awareness of the insidious effects of bias, focusing on how to positively reshape and enrich the identity narratives of women's roles in computing and IT.

We collected and analyzed stereotypical roles of women in computing and IT as included in news reporting and imagery, identifying stereotypes and associated themes. Their frequent appearance in the media continues to reflect the stereotypes of society in general, and now also in computing and IT education and employment. Moreover, stereotyping is constantly evolving and adapting. Moreover, regarding gender equality in computing/IT education and career choices, exposure to role images continues to influence decisions women make about their educational and professional lives.

We interpreted our observation results through the lens of today's dynamic IT and computing workforce that, for the sake of equity among all people, considers both genders when recruiting. In reality, though, gendered, race-targeted unfair treatment remains a barrier to gainful long-term employment, since underrepresented minorities and women often feel compelled to

PHOTO COURTESY OF HARVEY MUDD COLLEGE

leave their jobs due to unfavorable corporate/academic environments.

The nonrealistic profiles and nonpositive images of women in the popular media, along with underrepresented minorities and sociocultural groups, continue to warrant thorough investigation and redirection. Rather than be distracted by stereotypical (negative or controversial) images, researchers and media leaders should focus on the story (re)telling process and untold narratives to capture lived experiences and establish an inclusive climate for those historically underrepresented in the field. As research cited in this article indicates, imagery influences both future and current participation in computing and IT in terms of retention and reducing the number of "tech leavers." Other narratives of interest include underemployed and unemployed women and how the negative stereotypes seen in mass-media images might influence participation in such emerging career pathways as data science, cybersecurity/privacy, artificial intelligence, virtual reality, and machine learning. Computer science and related tech industries, as well as society in general, must promote equitable computing/IT roles and the associated images needed to represent inclusive media acculturation, role/work identity, and intersectionality.[3,13,26] Along with audiovisual artifacts with proper work-life balance,[8] inclusive women's roles in a multicultural context should be on the research and development agendas of educators, STEM leaders, and education policymakers. Inclusive, realistic role images/models could help increase the number of underrepresented minorities in academia and in the tech work force while strengthening and inspiring entrepreneurial mind-sets and pathways. C

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For more, see the online appendix "Media Representations of Women in Computing Through Text and Images" (dl.acm.org/citation.cfm?doid=3319422&picked=formats)

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