have had everything set up, and accommodate them, as and when they see fit." (HCIR1)

When researchers do not have visual or audio materials prepared ahead of time, the experience of working with production teams at the last minute can be time-consuming or unpleasant. However, another issue with multimedia production is that researchers do not have control over how sound bites or video clips are synthesized into a story, or else they cannot ensure that they will represent the research accurately under the pressure of live recording. *"I don't do radio or television because there is no editing after the fact, and I'm not generally articulate enough to say what I meant the first time." (HCIR10)* Thus, **multimedia are stressful to generate at the last minute, and researchers often do not often have the technical means or time to produce high quality multimedia ahead of press coverage.**

2.5 Rapid Deadlines, Rapid Responses
Journalists need quick responses. Yet, *"a lot of people are just busy or they just, I do find they don't respond timely." (FJ1)* Or, *"Especially with academics, I'll oftentimes get an email two days later that's like, oh yeah, I can speak to that next week, and I'm like, I needed it two days ago, thank you." (SR1)* With unforgiving deadlines, *"Sometimes a story just falls apart if you can't get anyone to comment on it." (FJ1)*

Some PIOs try to post press releases when HCIRs have increased availability, e.g. avoiding travel dates or conference deadlines. Nonetheless, seven HCIRs described challenges related to unpredictable demands for their time, since media requests can come in a deluge, dearth, or steady trickle. *"It's hectic. ... Once a release goes out, we're sort of reacting. Sometimes we'll get requests that come in to be interviewed, other times we'll just be waiting." (HCIR7)*

Furthermore, participants described conflicting desires related to collaborative interactions that must happen rapidly to meet deadlines. For example, some HCIRs prefer that reporters email questions rather than schedule calls. *"Usually asynchronous is easier to pull off. Plus I can copy/paste them, because a lot of people might have the same questions." (HCIR7)* But journalists want unique quotes, and from their perspective, *"People are so boring and dreary by email. You don't write the way that you talk, so I never do interviews by email. A lot of people want to do that, because then they can control exactly what's on the page. I don't let them do that." (FJ2)*

Many HCIRs also want to see drafts prior to publication, but *"most times, you don't get to see the article before they publish it." (HCIR2)* Conversely, journalists do not send drafts because researchers *"don't get how pressed for time we are, don't get what makes an interesting piece of science writing, and they will come back to you and they will make it twice as long and twice as boring. Then you get into this awkward conflict, where you don't want to upset them, but you just can't go there." (FJ2)* Thus, rapid deadlines are draining on journalists and challenging for HCIRs, who may prefer different interaction types. **Current technologies do not afford communication mechanisms that ease tensions between journalists and HCIRs during the short timeframes before deadlines.**

DISCUSSION

Results of our grounded theory analysis [10] denote two collaborative domains: the first between HCIRs and PIOs (i.e. research advocates), and the second between research advocates and media outlets. Here, we offer implications for design and future research in HCI across both domains.

1. Enhancing Collaboration with Research Advocates

In the first collaborative domain, research advocates share related goals as members of the same organization. PIOs must manage many relationships, events, and press interactions to raise their organization's profile. Most HCIRs are covered in the media infrequently, i.e. news coverage is not a primary incentive, although it may increase public awareness of research and have significant career benefits. Thus, PIOs occasionally work with HCIRs to share milestones, write press releases, prepare for media, and track coverage. PIOs have access to paid news services that provide information about journalists. However, other than email, participants did not describe existing technologies to support collaborative acts between research advocates. Results indicate that collaborative pain points can lead to missed opportunities for effective coverage, biased coverage only towards researchers who seek it, uncertainty about how press releases will be interpreted, inadequate media preparation, and incomplete knowledge of coverage breadth and quality. We suggest the following design implications for new technology to enhance collaboration; numbers correspond to subsection headers in Results:

1.1 Automated notifications for research milestones: Technology should make it easier for HCIRs to notify PIOs of milestones, and for PIOs to comprehensively assess milestones occurring across their organization. This could be achieved through simple UI prompts or features on submission platforms or organizational websites. **1.2 External feedback:** Technology should enable research advocates to understand how uninformed outsiders might interpret press releases. Models based on crowdsourcing or online communities like Reddit (which is now venturing into fact-checking) may offer promising mechanisms for discerning possible perceptions/receptions of releases before they are sent to journalists or posted publicly. **1.3 Training resources:** Technology should complement and assist PIOs with media training for researchers, possibly through online educational tools like massive online open courses or online communities that allow researchers to share experiences of press engagement and mentor each other. Automatic templating tools or bots might also be helpful for scaffolding public-facing language or practicing for press engagement (see Quartz' news bot [46] as a potential conversational model). **1.5 Tracking coverage patterns:** Technology should not only make it easier to see and understand coverage instances across many platforms and media formats (esp. on social media sites), but also to trace coverage patterns and provide corrective feedback mechanisms for emergent errors.

2. Enhancing Collaboration with Media Outlets

In the second collaborative domain, tensions between research advocates and media outlets can make it hard to collaborate against rapid deadlines on story identification, communication of methods, provision of expertise, and multimedia production.

News services facilitate the embargo system, yet they also contribute to information overload and are not heavily utilized by journalists, who rely more heavily on social media [24, 28] and take professional pride in their curated relationships with quality sources [38]. With production jobs being cut at many media outlets [8], journalists must work under increasing pressure to write, produce, optimize, and publish numerous stories to online platforms. However, HCIRs operate on different timescales and incentive structures that do not often align with journalists. Results indicate that this juxtaposition results in numerous failed or strained communication attempts, insufficient lay resources on new scientific methods and expertise, and frantic scrambles to produce multimedia. We suggest:

2.1 News service improvements: Future innovation should make it easier to gauge the relevancy of releases (possibly via recommender systems), or by reconceptualizing the system design for how, by whom, and when press releases are accessed, possibly considering mechanisms that implement matchmaking algorithms, (temporarily) exclusive access through information marketplaces, or online networking functions. **2.2 Lay resources on methods:** Technologically mediated resources should provide up-to-date and lay-accessible descriptions of contemporary scientific methods, possibly via peer production. For example, researchers could contribute to a StackOverflow-, Quora-, or Wikipedia-like community specifically for emergent scientific methods, or contribute additional information layers to online content via annotation (e.g. the model put forth by hypothes.is [29]). **2.3 Contextualizing expertise provision:** Future tools for helping journalists get in touch with relevant scientific experts should implement mechanisms that convey relevance and trustworthiness of experts, potentially by exploring technical use of citation databases and funding sources in a "sense-making" manner, so that journalists can understand who paid for research, where ideas fall along the intellectual spectrum, and whom to contact for expert comment. Importantly, new tools should also make it easier for experts to understand what type of information journalists need ahead of interviews. **2.4 Continual multimedia generation:** Technology should ease last minute production stress by offering a simpler means of collecting and synthesizing visual and audio materials throughout the research process rather than at the last minute. Crowdsourcing could be used to produce compelling multimedia to share on social media or directly with media outlets. **2.5 Accommodating deadlines via novel collaborative techniques:** Technology should provide new modes of interaction between researchers and journalists that enable journalists to rapidly get required information, and researchers to avoid repeatedly answering the same questions. This might be achieved through tools for mediating interviews with multiple attendees (e.g. virtual press conferences) or aggregating journalists' questions and allowing researchers to record/distribute audio/video files to desired journalists.

Limitations

Because this work is qualitative in nature, we describe results from a relatively small group of stakeholders. Thus, our participant sample is not necessarily representative of all possible stakeholders and may be affected by self-selection bias. HCIRs in our sample are primarily academic, and almost all participants are from Western cultures. Despite attempts to recruit more industry participants and participants from Eastern cultures, we did not receive many replies, possibly due respectively to internal policies (re: increased concerns about anonymity) or timezone and cultural differences. Furthermore, this work focused on production of HCI-related scientific media. Although most parts of the presented MPP infrastructure and design opportunities may be common across scientific disciplines, different disciplines may face unique challenges. Future work should investigate opportunities for other areas and geographies in science communications.

Conclusion

In the modern Web 2.0 information environment, stories can go viral in the blink of an eye regardless of their legitimacy. Their authors are not only trained journalists, but also scientists, lay citizens, and powerful political and corporate interests, often pitted against each other in a battle for credibility. With a crisis of faith in mainstream media well underway, combined with an onslaught of science-decrying public figures spreading misinformation like wildfire, the institution of science is at a critical juncture. Scientists must speak up, and they must do so effectively if their voices are to be heard through the chaotic information churn of Web 2.0.

This paper describes the MPP for producing scientific content in Western media systems. As we have shown, much can be done to enhance collaboration with media outlets, yet scientists' willingness to engage is clearly a prerequisite–and a point of opinionated contention. "Visible Scientists" [17, 23] who operate prominently in the public sphere can potentially use their influence to affect policy/public opinion. Yet researchers risk reputations as "show boaters" who egotistically pander to the media or sacrifice the quality of their work to focus on career advancement through increased popularity [17]. Academics rely intensely on citations to demonstrate scientific contributions, yet media engagement is of value to society and requires real work. We believe there exists a middleground. Technology can possibly reduce the time and effort required of scientists to share newsworthy research responsibly with the public, and perhaps even improve scientific literacy rates, though it remains critical to consider how peoples' "folk theories" [5] interact with reception of science news. We have suggested implications such as automatic tracking of research coverage in mass media, as well as expert contributions to credible and lay-accessible online resources–both of which yield quantitative metrics. In order to truly bridge the gap between science and society, the academy ought to not only study and build new media tools and systems, but also formally expand incentive structures to consider measures of public scholarship through high quality and impactful independent media production or mainstream media engagement.

Acknowledgements

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