MAJOR RESEARCH QUESTIONS

[MSB: this needs a transition into it. Before you lay out our method, lay out what we're trying to do. What's our goal here? THEN the method can explain how we achieved it. This might involve switching the order of some of the text here]

We look at lots of papers that use the term "crowdsourcing" or "crowd work" in the abstracts and titles of their papers, especially the papers that we cited earlier, to try to answer the questions that we posed in the introduction. Then we look to the piecework literature to see whether and to what extent piecework answers the questions we, crowdsourcing researchers, have asked. We then see whether and how crowdsourcing as we know it has differed from piecework, and how that affects the predictions and conclusions made in the piecework literature.

What are the limits of crowdsourcing?

Research in crowdsourcing has spent the better part of a decade exploring how to grow the limits of crowdsourcing and find the boundaries of crowd work and microtasks. This has largely involved identifying challenges to this form of labor, overcoming them through novel designs of work–flows and processes, and repeating the process [e.g. 3, 54, 32]. The question that has emerged among these researchers and through the work that they have produced then has been driving at *whether* there are limits to crowdsourcing (and, if so, what factors determine those limits). Through this lens, we can point to a number of contributions to the field that have extended the boundaries of crowd work.

The exploration of crowdsourcing's potential and limits has principally looked at manipulating and extending along three dimensions: 1) What are the limits of crowd work, 2) How far can work be decomposed into smaller and smaller microtasks, and 3) What will work and the place of work look like for workers. We'll explore these aspects of crowdsourcing, discussing the extents to which work can be decomposed, contextually abstracted, and made more resilient to attrition of various forms. We'll also point to corresponding piecework literature addressing these aspects. [MSB: Our goal will be to use that literature to inform answers to the questions about crowd work (or something like that)] Finally, we'll discuss how these elements will serve to constrain the upper and lower bounds of crowdsourcing as it relates to the question of the furthest limits of crowdsourcing.

Identifying the Limits of Crowd Work

Crowd work's perspective. **Crowdsourcing research has spent the better part of a decade attempting to prove the viability of crowdsourcing in increasingly complex work.** Kittur et al. map the discussion toward this goal in their work on crowdsourcing complex work [32]. The broader body of work has varied significantly in type — providing conversational assistants, interpreting medical data, and telling coherent and compelling stories, to name a few examples [37, 47, 30].

This body of research has involved similar approaches to problems, often involving insights made in Computer Science and applied to human work–flows. The crowd work literature typically identifies target milestones in computer science that have presented significant challenges for researchers, leverages some of the approaches and insights that Computer Science researchers have already made (for example, MapReduce in the case of Kittur et al.'s *CrowdForge*), and arranges humans as computational black boxes within those approaches and processes [32, 54, and others]. This approach has proven a compelling one because it leverages the in–built advantages that technology and digital media afford. For example, *Foundry*'s tools for managing and arranging expert groups into a cohort allow researchers to convincingly argue that expert teams can be rapidly formed, just like non–expert teams [54].

Piecework's perspective. **Piecework researchers have found themselves trying to understand what characteristics limit piecework, or more precisely what has prevented piecework from becoming more prevalent.** The research into piecework makes the case that piecework has been limited principally by the challenges of human management and oversight. Graves describes a case study in Santa Fe Railway, which deployed scientific management and a piecework regime in an attempt to stymie rising repair costs [16]. Graves reports on the hiring of Harrington Emerson, an "efficiency expert", who went on to develop a "standard time" for each task at the company informed by "thousands of individual operations at the Topeka shops". The cost of measuring workers in such excruciating detail at the turn of the 20th century was undoubtedly immense, but this "standard time" value, which determined the pay that workers would earn for each task they do, was the only viable approach at the time to determine appropriate pay given the task [16]. But the repeated measurement of workers' time to complete tasks had shortcomings; for one thing, pay rates for rarer tasks were necessarily less certain than for more common tasks, which had the simple benefit of a larger sample size. [al2: Do I need "for another thing..."? This paragraph is kind of huge already. Not sure how to break it up/down as it is.] One might conclude from Graves's observations that complex, creative work — which is inherently heterogeneous and difficult to routinize — would be unsuitable for piecework.

Determining appropriate pay rates, informed by the careful measurement of workers, isn't the only major challenge piecework faced; evaluation proved a limiting factor as well. Graves enumerates some of the roles required to facilitate piecework in the early 20th century — among them "... piecework clerks, inspectors, and 'experts'..." [16]. Graves further recognizes that it's necessary for a successful piecework shop to employ clerks, inspectors, and other experts to properly design and evaluate complex work. Hart later makes a more concrete observation of this hurdle, as he argues an ultimate limit to how far this can go; at some point, evaluating multidimensional work output for quality (rather than for quantity) becomes infeasible. In his words, "if the quality of the output is more difficult to measure than the quantity, perhaps because of 'difficult–to–observe' production techniques, then a piecework system is likely to encourage an over–emphasis on quantity produced and an under-emphasis on quality" [22]. This, Hart argues, may have fundamentally hamstrung piecework, and ultimately precipitated its downfall,

especially with the increasing complexity of manufacturing work over the course of the 20th century. [al2: just to be clear, this whole point is queuing up so that later I can be like "Oh hey computers are terrific at evaluating some stuff really quickly. And researchers in crowd work have done some work on workers evaluating other workers (e.g. Find–Fix–Verify, arguably *PeerStudio* does something along this line) [3, 35]"]

The research seems to suggest that it was difficult to apply piecework to more skilled work, particularly because maximizing on the advantages of piecework seemed to reward smaller, more constrained, more narrowly trained tasks. For most of the 19th century, piecework was applied almost exclusively to farm and textile work. Work was simple and widely understood — farm workers didn't need to be trained on how to plow fields, or birth foals; seamstresses knew how to sew together denim [9, 55].

This isn't to say that complex work is outside of the realm of piecework; indeed, we've discussed complex applications of crowd work already. While Hart and Roberts described a flourishing of ingenious piecework design, much of it arose out of necessity — it was infeasible to provide new workers with the comprehensive education that was familiar to men through apprenticeships [21]. While this constraint led to much more tightly scoped work who now had to specialize in extremely narrowly defined roles. The same could be said of Airy and his *computers* — young boys whose preparations consisted principally of a relatively specific mathematics curriculum [19]. Instead, we argue that the literature suggests that piecework is tightly limited only when the application of piecework follows a direct, perhaps even unimaginative, mapping from an time–based regime to an output–based one. When the work is redesigned from the ground up — as we see with mathematicians in the 19th century and with the metal-working industry during the Second World War — it seems that we don't yet know the limits of complexity with regard to piecework. [al2: This is *almost* making a prediction, but I wanted to take something punchy away from the stuff I cite here.]

Piecework researchers also argue that, in addition to constraints on the kind of *work* that's amenable to piecework, only certain kinds of *organizations* are amenable to piecework. Brown discusses the organizational factors necessary for piecework to thrive, arguing that piecework "... is less likely in jobs with a variety of duties than in jobs with a narrow set of routinized duties" [6] Graves adds further, that successful cases of piecework owed themselves in part to the fact that "... only [the largest and most wealthy railroads] had the resources to ... pay the overhead involved in installing work reorganization" [16]. Together, Graves and Brown make a persuasive argument that piecework is limited in complexity by the capacity to endure managerial overhead while transitioning to a new system. [MSB: wait, wasn't that in a previous paragraph? that should be joined with the managerial overhead text above] [al2: I'm trying to make this argument that [16] is making two claims; the first is that there are limits on doing hard, "difficult–to–observe" work, and the second is that the cost propagates up to management, putting limits on who can run piecework systems. So. . .

☐ Rewrite
☐ Refactor
☐ Drop

Maybe I should just merge it with the next paragraph?]

There are other characteristics to effective complex piecework institutions, such as appropriately designed management practices. Boal and Pencavel describe the role of the foreman in West Virginia coal mines under the piecework model: "The foreman had the power to hire and fire workers and allocate workplaces, but then left the face–worker largely free to his own efforts so that often he went all day without seeing the foreman" [4]. The general approach adopted by these West Virginia mines was, as in other factories with active foremen, to let the foreman be the intermediary between management and the worker. Specifically, foremen were responsible for allocating resources and understanding when and how to modify work as necessary [70]. The management of pieceworkers demanded people in positions akin to foremen — intermediate managers people who were 1) familiar with and even sympathetic to the needs of workers, 2) empowered by higher level management to make decisions, and 3) relaxed enough in day–to–day work to allow workers to go about their work [70, 4].

What's different about crowd work. [MSB: Before you get into this, summarize what I am supposed to have learned from the prior section on piecework. You're about to draw on those points to make your argument, so they need to be at the top of my mind here.] **Piecework makes a number of observations leading to the conclusion that piecework's complexity is fundamentally bounded by several limitations, chief among them the costs of managerial overhead and the transition thereto.** Brown and Graves's claims that organizations can't adopt piecework unless they're sufficiently large to absorb the cost of transitioning to a piecework system; Boal and Pencavel and Wray's observations for the importance of competent, effective managerial oversight — a human resource, which made the scaling cost prohibitively expensive for many [4, 70, 16, 6]. [al2: Something like this? Should I dig deeper? I can line these points up in a way to make the next paragraph sort of obvious or inevitably, depending on how actively engaged someone is while reading this. . .]

Digital media have expanded the scope of viable piecework by pushing drastically on the limits cited by piecework researchers. The research on piecework tells us that we should expect piecework to thrive in industries where the nature of the work is limited in complexity [6]. Given the flourishing of on–demand labor platforms such as Uber, AMT, and others, we ask ourselves what — if anything — has changed. We argue that the Internet has trivialized the costs and challenges of the earlier limiting factors because technology make it easier 1) to do complex work aided by computers and 2) to evaluate and manage workers as they do increasingly complex work, even observing their work to an otherwise unprecedented granularity.

Technology has made it possible for non–experts to do work that was once considered within the domain of experts. [MSB: I don't yet buy the following argument. If the point is that technology makes us more expert, I disagree that the CrowdCrit/Voyant systems are using technology to do this. They are building the smarts into their OWN workflows, rather than giving workers EXTERNAL tools that make them smarter. Giving workers a calculator is an external tool; the mathematical tables project already demonstrated that you can build smarts into the workflow if you don't have one.] Yuan et al. builds on the work of others (*Voyant* and, more relevantly, *CrowdCrit*) to design workflows that yield "expert–level feedback" [72, 71, 43]. This body of work identifies ways to transform a variety of duties comprising complex tasks and distills them into "a narrow set of routinized duties", informed in part by researchers — acting as inspectors — and experts [quotations from 16]. Where Graves would call additionally for the identification of crowdsourcing's version of "piecework clerks", we point out that today algorithms manage workers as pieceworkers once did [40, 16].

Furthermore, technology more directly facilitates the subversion of expertise requirements by giving non–experts access to information that would otherwise be unavailable. Taxi drivers in London endure rigorous training to pass a test known as "The Knowledge" — a demonstration of the driver's comprehensive familiarity. Researchers have identified significant growth of the hippocampal regions of the brains in veteran drivers, generally understood to be responsible for spatial functions such as navigation [45, 44, 60, 61, 69, 68]. Services such as Google Maps & Waze make it possible for people entirely unfamiliar with a city to know more about a city even than experts through the collective data generated by other users ranging topics such as police activity, congestion, construction, etc... [59, 23]. [MSB: what's the insight I should take away from this paragraph? what does this say about crowd work?]

Implications for crowd work research. [MSB: This paragraph can be expanded to make a more concrete argument. What will be possible? What won't?] **The piecework literature gives us a template for pushing the boundaries of complexity in piecework, but it also signals some of the ultimate limitations of crowd work and piecework in general.** While the threshold preventing task requesters from utilizing piecework has dropped thanks to affordances of the Internet, the ceiling on task complexity hasn't moved significantly. [MSB: is that your prediction? I would argue against the fact that it hasn't moved significantly, crowdforge did far more complex work, as did flash teams and flash orgs] If we're to make use of Brown's prescriptions, we would benefit from finding ways to decompose varied tasks into homogeneous microtasks. [MSB: isn't that what we've been doing all along?]

[MSB: this doesn't seem like a concrete prediction. what would piecework say will happen if we didn't resolve the tension?] We should also consider exploring the limitations that algorithmic management bring along more carefully. While research has touched on this subject, we've yet to make out the bigger picture of this theme [40]. If we can resolve the ten-

sion between workers and perilously antagonistic managers, as Boal and Pencavel suggest, then we may be able to break a toxic cycle of mistrustful requesters [for example 15] and develop more considerate platforms as McInnis et al. advocate [49].

Finally, and perhaps most importantly, we need to replicate the success of narrowly slicing education and training for expert work as Hart and Roberts and Grier described in their piecework examples [21, 19] [MSB: remind us of what those were]. That is, we need to identify new ways to train crowdworkers for uniquely narrowly defined work. [MSB: I don't understand: why?] To some extent, an argument can be made that MOOCs and other online education resources provide crowd workers with the resources that they need, but it remains to be seen whether that work will be appropriately valued, let alone properly interpreted by task solicitors [1]. If we can overcome this obstacle, we might be able to empower crowd workers to do complex work such as engineering and metalworking, rather than doom them to match girl reputations: "brash, irregular, immoral, and uneducated" [57]. [MSB: how will that reduce any of the problems except the last one?]

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Decomposing Work

Crowd work's perspective. **The crowdsourcing research into work decomposition has largely focused on minimizing the additional context necessary to do tasks, and making it easier to do tasks with less time.** This first thread is perhaps best described by Verroios and Bernstein as making crowd workers "...able to act with global understanding when each contributor only has access to local views" [66]. With the exception of a few cases (specifically, Kinnaird, Dabbish, and Kiesler's work which finds that greater work context fosters more reliably high–quality work), the micro task paradigm has emerged as the overwhelming favorite [62, 63, 11, 31].

As the additional context necessary to complete a task diminishes, the marginal cost of finding and *doing* tasks has increasingly become the focus of research. Chilton et al. illustrate the challenges on AMT, and some work has gone into ameliorating the problems specific to this work site (*Re-Launcher*), while other work designs tasks around gap time (*Twitch Crowdsourcing & Wait–Learning*) [12, 34, 65, 8]. Cosley et al. attempts to address this by directing workers to tasks through "intelligent task routing" [13]. Much of this work and the work at the periphery of this space, then, has focused on minimizing the amount of time that people need to spend doing anything other than the work for which they are paid.

Earlier we discussed Cheng et al.'s work measuring the impact that interruption has on worker performance [11]. This work illustrates a broader sentiment in both the study and practice of crowd work, that microtasks should be designed resiliently against the variability of workers, fully exploiting the abstracted nature of each piece of work [25, 38, 64]. That is to say, micro–tasks should be designed such that a single worker's poor performance, or a good worker's sudden departure, does not significantly impact the agenda of the work as a whole. While Cheng et al. found costs with breaking tasks into smaller components in the form of higher cumulative time to complete (albeit much shorter real time to complete, owing to parallelization), Lasecki et al. found that at least *some* performance can be recouped by stringing similar tasks together [11, 38, respectively].

Yet more work looks at the general framing of tasks, chaining and arranging them to maximally exploit the attention and stress threshold of workers [7]. Rather than attempt to minimize the error rates in micro–tasks, as Kinnaird, Dabbish, and Kiesler suggested, we as a community have leaned *into* the peril of low–context work, "embracing error" in crowdsourcing [33].

Piecework's perspective. **The research community relating to piecework and labor has been wrestling with the decomposition of work for centuries.** The beginnings of systematic task decomposition stretch back as far as the 17th century, when Airy employed young boys at the Greenwich Observatory who "possessed the basic skills of mathematics, including 'Arithmetic, the use of Logarithms, and Elementary Algebra' " to compute, by hand, astronomical phenomena [19]. These workers became the first *computers*.

The work Airy solicited was interesting for several reasons. First, work output was quickly verifiable; Airy could assign variably skilled workers to compute values, and have other workers check their work. Second, tasks were discrete — that is, independent from one another. Finally, knowledge of the full scope of the project — indeed, knowledge of anything more than the problem set at hand — was unnecessary.

The insight of breaking tasks down into smaller components didn't find its audience until the early 20th century, with the rise of Fordism and scientific management (or Taylorism). From scientific management, we found that we could measure work at unprecedented resolution and precision. As Brown points out, piecework most greatly benefits the instrumented measurement of workers, but certainly in Ford and Taylor's time — and certainly in Airy's time — highly instrumented, automatic measurement of workers was all but impossible. As a result, the distillation of work into smaller chunks ultimately reached a limit of usefulness.

What's different about crowd work. **A number of factors in crowd work are different from piecework, chief among them being the relative ease with which the metaphorical "assembly line" can be changed.** Computers make it possible to switch from one task to another unlike any arbitrary manufacturing factory possibly could; a worker could do any number of different *types* of tasks in the span of just a few minutes, driven in particular by the power Lessig points to — that system–designers can share, modify, and instantiate environments like sites of labor in a few lines of code [38, 41]. This has spurred an entire body of work investigating the effects of ordering, pacing, interruptions, and other factors in piecework that would have been all but impossible to measure consistently as few as 20 years ago [11, 10, 33].

Further, we've sliced work to such small scales that the marginal activities — things like finding work, cognitive task switching, etc...— have become relatively large compared to the tasks themselves [12]. In the historical case of piecework, moving metallurgical tools, mining equipment, or other industry materials would have been prohibitively difficult and slow; workers were encouraged to specialize in a single set of tasks, allowing pieceworkers to sequence their tasks optimally on their own [21].

Rather than fall into the trap that Irani warns of, — one which where crowd workers are rendered as "modular, protocol–defined computational services" — we may yield better results from crowd work if we think of workers as similar to specialized, repurposable tools [26]. [al2: feeling meh about this argument...]

Finally, instrumentation has reached a sufficiently advanced and ubiquitous point that the dream of scientific management and Taylorism — to measure every motion at every point throughout the workday and beyond — is not only doable, but trivial [67]. One of the major challenges Graves cites as preventing scientific management from being fully utilized, the difficulty of tracking work & workers, no longer exists [16].

Implications for crowd work research. crowd work research today is on the right track to investigate pipelining and meta–task design. That is, investigating better work discovery methods, producing tools for workers to make more informed decisions [see, for example, 28]. It's not clear how much benefit there is in the further decomposition of work, given that we've hit bottlenecks with the cognitive stresses of switching between tasks as Lasecki et al. highlight [38].

The Relationships of Workers to Work, Peers, and Others
Crowd work's perspective. **The relationships of workers with their peers and with requesters are nuanced and not especially well–understood.** Researchers have begun to appreciate the sociality of crowd workers in labor markets; still, the study of these communities is made more challenging by the limited access to workers on these sites of work inherent to digital spaces made without social affordances [18, 52]. We can break this general body of work into two subgroups: workers' relationships 1) with *requesters*, and 2) with *other workers*. We'll look at workers' relationships with work itself, which we'll discover gives us insight into why people engage in crowd work in the first place.

[al2: some topic sentence that brings together the debate where one side blames Turkers for being bad at Turking and another side blames requesters for not understanding Turkers as a culture of people.] Some research frames this tension as the Turker's problem (see, for example, Gadiraju et al.'s work, which frames the problem of unpredictable work as the result of "malicious" crowd workers), [15, 58, 24].

Early on, Irani and Silberman highlighted the information asymmetry between workers and requesters on AMT, leading to the creation of *Turkopticon*, a site which allows Turkers to rate and review requesters [28]. Salehi et al. took this critique on information asymmetry and power imbalances a step further, designing *Dynamo* to facilitate Turkers acting collectively to bring about changes to their circumstances — this led to the Academic Requester Guidelines [56]. This unbridled power that requesters have over workers and the resultant stress and frustration that this generates has been part of the undercurrent of research into the tense relationships between workers and requesters [17, 56].

The frustration that workers experience dealing with requesters seems to precipitate frustration and mistrust between crowd workers, as well. Salehi et al. describes "mega–drama" among workers on forums for Turkers; Irani and Irani and Silberman discuss the culture of crowd work and the study thereof. Gray et al. quantifies and maps this social network of Turkers. McInnis et al. takes these observations and considers what a crowd work platform might look like if it were to be designed more inclusively [56, 26, 27, 18, 49]. The overarching theme of the research in this space has been documenting the struggle of crowd workers and attempting to intervene in constructive ways, while walking the balancing act (especially in the cases of Irani and later Irani and Silberman) as we think about the culture of crowd workers.

Piecework's perspective. **The questions surrounding the ways pieceworkers related to managers might be best answered by the work that has been done in the emergence and proliferation of labor unions.** The primary avenue for workers to interact with managers has been through laborer advocacy groups such as the American Federation of Labor, (one of the forerunners of the largest and most politically influential labor union in the United States). Looking through that lens, we find copious research on the relationships between workers and requesters [42, 2, 48, 29]. One component of collectively negotiating with managers has been the process of collective action, a topic which has been substantively explored but is not quite yet answered [20, 53].

Answering how workers related to one another is arguably more challenging for a number of reasons. For one thing, the research methods we typically associate with the exploratory study of cultures — Anthropology, and namely participant–observation, ethnography, etc... — didn't exist quite as we know them at the turn of the 20th century, and wouldn't for several more decades. Still, we can look at primary sources, like *The problem of piece work* to give us some hint of how they related to each other [36].

[al2: What do I want to do/say here? I think I want to point to point out that ~~... I dunno. I'll review the~~ *The problem of piece work* ~~book and maybe some other stuff~~ okay after reading the intro I feel like the big takeaway is the need for workers to associate "note only as railroad employees but also as members of the larger life of the community" and other notions of affiliation and recognition of shared underlying goals and hopes. I could point to Riis and be like "what *he* did was illustrate through this relatively new medium — photography — how bad pieceworkers had it, foreshadowing this later urging by nascent labor advocacy groups to recognize that workers all shared these problems and needed to associate."

This can also foreshadow crowd sourcing efforts like *Turkopticon* and *Dynamo*.]

What's different about crowd work. **The differences between crowd workers and pieceworkers seem defined largely by the differences in the places of work.** Whereas it arguably became inevitable that workers would have a place to meet, discuss, and collaborate when they began sharing places of work, online spaces make it much harder to do so. Crowd workers can "lurk" and do tasks, or just do the occasional one–off task, without any affiliation with — or even knowledge

of — communities of peers [al2: multiple citations that labor unions came out of factories here] [52, 50, 14].

While the historical management of workers had to be done by hiring a foreman, who necessarily had an intuitive — perhaps sympathetic — relationship with workers, the foreman of the 20th century has largely been replaced by the algorithm of the 21st century [40]. The result of this change is that the agents managing work are now cold and logical, if unforgiving. Where a person might recognize that the "attention check" questions proposed by Le et al. ensure that malicious and inattentive are stopped, some implementations of these approaches ([see 15] only seem to antagonize workers [39, 15].

Implications for crowd work research. **What we've done in the field of crowd work might be able to tell us something about piecework just as piecework has told us so much about crowd work.** Crowd work research doesn't just benefit from digital media allowing us to make relationship networks like Gray et al. do; we benefit from the firmer theoretical basis of Anthropology that existed in a radically different form at the turn of the 20th century, when piecework began to emerge. Malinowski, Boas, Mead and Boas and other luminaries throughout the first half of the 20th century effectively defined Cultural Anthropology as we know it today; *participant–observation*, the *etic* and the *emic* understanding of culture, and *reflexivity* didn't take even a resemblance of their contemporary forms until these works [46, 5, 51].

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