MAJOR RESEARCH QUESTIONS

We look at lots of papers that use the term "crowdsourcing" or "crowdwork" 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. 4, 52, 33]. 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) finding crowdwork's limits, 2) slicing work into smaller parts, and 3) worker volatility. 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. 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.

Achieving greater complexity — or "making crowd–work yuge"

Crowdwork'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 [33]. 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 [36, 45, 32].

This body of research has involved similar approaches to problems, often involving insights made in Computer Science and applied to human work–flows. The crowdwork literature typically identifies target milestones in CS 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 [33, 52, and others]. This approach has proven a compelling one because it leverages the in–built advantages that technology and digital media afford. *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 [52].

Piecework's perspective. **The research into piecework makes the case that piecework has been limited principally by the challenges of human management and oversight.** Graves, who describes piecework as "... based on examination of various shop jobs, which included calculation of the standard time and compensation for each task", argues that piecework must be rigorously evaluated at a time that demands *other people* perform the evaluation. Graves later enumerates some of the roles required to facilitate piecework in the early 20th century: "... piecework clerks, inspectors, and "experts"..." [20]. This criterion strictly limits the extent to which piecework can grow in complexity; it must, for instance, be quickly evaluable by another person.

Piecework researchers also make claims regarding the organizations that benefit from piecework in the first place. Brown discusses the factors necessary for piecework to thrive: "... incentive pay is less likely in jobs with a variety of duties than in jobs with a narrow set of routinized duties" [7]. 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" [20]. Together, Graves and Brown make a persuasive argument that piecework is limited in complexity by managerial overhead and the fixed cost of adopting a piecework payment regime.

What's changed. **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. Given the flourishing of on–demand labor platforms such as Uber, Amazon Mechanical Turk, 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 for two reasons: 1) Technology make it much easier to do complex work aided by computers; and 2) The Internet allows us to leverage the benefits of "economies of scale" at very little cost to the system–designer [39].

Technology has made it possible for non–experts to do work that was once considered within the domain of experts. Yuan et al. builds on the work of others (*Voyant* and, more relevantly, *CrowdCrit*) to design workflows that yield "expert–level feedback" [79, 78, 42]. 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 20] 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 [38, 20].

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 [44, 43, 64, 65, 77, 76]. 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. . . [63, 23].

Crowdsourcing falters when the routinization of complex work proves difficult. [al2: Something about complexity being difficult to make routine when there are lots of little tasks a la Brown]

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PARAGRAPH GRAVEYARD

great topic sentence here. Teevan, Liebling, and Lasecki push the boundaries of decomposed work, exploring "self-sourcing", and further this work with Teevan et al. [68, 69]. While some of this work doesn't strictly fall under "crowdsourcing", the [scientific] management of the self as a worker (of sorts) will prove relevant as we trace the literature surrounding piecework.

This is also kind of off-topic, isn't it? where to take it?

A smaller but growing body of work has reflected on this and brought to our attention a number of ethical questions surrounding the increasing complexity of crowdwork and the hazards that increasingly arise. Silberman, Irani, and Ross bring some of these issues at stake — working for increasing amounts of time on tasks of growing complexity, only to discover that requesters are not willing to pay, for instance — but these and other dangers range an enormous landscape [34, 61, 48, 57].

We summarize the work discussed so far in this way: researchers of crowdsourcing and on–demand labor in general have attempted to find the characteristics which enable and stymie successful applications of this form of work, and how to get past or around these boundaries. Whether this work has focused on the self (as in the case of "selfsourcing") or on others (as in *CrowdForge* and *Foundry*), crowdsourcing literature has generally studied the constituent work and attempted either to work around or indeed with the limitations of crowdwork to accomplish a difficult task [68, 69, 33, 52].

Crowdforge, turkomatic, others talk about limiting factors; bring them up

Talked to someone about this section and got some feedback...

1. Explain what "clever arrangement of work" in the first paragraph means (should be simple; Find–Fix–Verify is the *sort* of thing I mean);
2. I should make the "selfsourcing" stuff clearer for people unfamiliar with it (maybe even to justify its placement here); and
3. I should break up Graves & Brown to make the historical stuff on piecework directly speak to the three previous paragraphs.
4. (Maybe?) summarize the piecework stuff (the last paragraph approaches that, but more could be done).

Thoughts on this?

Graves also argues that a significant obstacle to the introduction of piecework in railroad shops was the resistance of workers (the other being the resistance of management (for different and varying reasons)). In the cases of online platforms like AMT and digitally mediated platforms like Uber, where in both cases workers rarely if ever interact face–to–face and opportunities for coordination and collective action are severely limited, we should expect to see the challenges stymieing collective action that we see in Salehi et al. and elsewhere [20, 57].

Slicing work smaller — or "putting the 'micro' in microwork"

Concurrent with the body of work on the complexity of crowdsourcing has been a thread of work exploring the decomposition of work. In this section we'll discuss some of the approaches and the results the crowdsourcing community have taken from their work. Then, as previously, we'll discuss some of the findings that piecework research has yielded. Finally, we'll discuss similarities and differences between crowdwork and piecework, and how crowdwork's limitations and potential differ from piecework's.

Crowdwork's perspective. Crowdsourcing research as it relates to began in earnest

One of the emergent properties of micro–tasks has been the relative cost of *finding* worthwhile tasks. The research community has documented and to some extent attempted to intervene in the discovery of worthwhile tasks [11]. Cosley et al. attempts to address this by directing workers to tasks through "intelligent task routing" [12]. 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.

Piecework's perspective. The beginnings of systematized 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* astronomical phenomena [21]. Airy's tasks were unique at the time for several reasons:

1. each task was quickly verifiable by a qualified [human] computer,
2. tasks were discrete — independent from one another, and
3. knowledge of the full scope of the project — indeed, knowledge of anything more than the problem set at hand — was wholly unnecessary.

What's changed. [al2: todo]

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PARAGRAPH GRAVEYARD

The finding here is that crowdwork can be more carefully micro–managed than piecework could be, and that this is a double–edged sword: we can effectively give feedback to workers on everything they do, but this is emboldening us to try to over–manage workers just as piecework tried to do.

My goal for this section is to make two points:

1. show how this is related to the assembly line and scientific management, and how piecework literature tried to measure everything, but found it untenable given the extra equipment that was necessary (but generally which didn't exist) to track every movement and action that workers took.
2. show how this work was enabled by the "verifiability" of work output(?)

Volatile quality and availability? How much can you deal with? [al2: TODO:

1. segue
2. Crowdwork's perspective.
3. Piecework's perspective.
4. What's changed.

]

A number of researchers have identified worker attrition, variability of worker performance, and uncertainty about good versus bad–faith actors as open questions of crowdwork [17, 26]. [al2: We can and should discuss the distinction between presumably "bad faith" workers & workers who are merely responding in kind to bad requesters — and the broader questions surrounding the roles that requesters as well as workers should play — but let it suffice to say that requesters have been trying to understand and manage what appears to them as inconsistent work. Their ways of responding to that variance in work quality has largely involved making the work more flexible and resilient to work (although some work has gone into investigating the causes, rather than treating the symptoms)]

Earlier we discussed Cheng et al.'s work measuring the impact that interruption has on worker performance [10]. This work illustrates a broader sentiment in both the study and practice of crowdwork, that microtasks should be designed resiliently against the variability of workers, fully exploiting the abstracted nature of each piece of work [27, 37, 73]. 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 [10, 37, respectively].

Krishna et al. take a different approach; by "embracing error" and forming models describing the latency of workers in classifying objects at rapid speeds, the authors offer orders–of–magnitude improvements in various binary classification tasks [35]. And rather than building tasks to *tolerate* worker drop–off and attrition, some researchers have designed work predicated on the expectation of it instead: Celis et al. describe ways of assigning tasks in such a way that crowd workers would never be given enough information to piece together sensitive information about any single topic [8].

The work thus far seems to attempt to maximize the quality of work among workers through various means: 1) Identifying "bad" workers (fraught with problems as this characterization is) [17], 2) Designing tasks with break points to facilitate the on–boarding and off–boarding that happens anyway [10], and 3) Expecting certain levels of attrition and incorrectness and using that variability to their advantage [35].

Flexibility has been explored through the lens of Fordism, perhaps best illustrated by Tolliday and Zeitlin's treatment describing turnover rates rising above 300% in the decade leading to the introduction of the assembly line in 1913. Specifically, the utilization of "... 'semi–special' machine tools which could be adapted [and] ... added flexibility through seasonal layoffs for production workers and the use of piece rates ... rather than a day wage system" [71].

In the field of piecework, the research covering this topic has both explored a breadth of tasks that might be rendered doable by piecemeal workers *as well as* longitudinally documented the success of these approaches. Here, we

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Graveyard of old paragraphs

[0] Here, Hu's work, saying of assembly line work that "it is assumed that men are of equal ability and every man can do any of the *n* jobs", parallels the approach that dominated early research into crowd work — namely, using non–expert crowds for complex work [25]. This mindset in Hu's analysis, and indeed the study of factory and mass manufacturing labor through the 20th century, substantively owes its existence to scientific management and the rigorous decomposition of work into tasks, discussed earlier, and persists to this day as it colors researchers' goals and objectives in the study and design of crowd work.

Piecework's influence on the abstraction of work into tasks, described above, is more than just caused by the decomposition of work; work abstraction itself makes it possible for workers to come and go flexibly, prompting work requesters to consider ways to design these now discrete tasks in ways that maximize flexibility, both by allowing (and even anticipating) some inconsistency in worker availability *and* allowing and anticipating some inconsistency in the quality of the work output itself. It's to this area that we now turn our attention.

Piecework has seen work along this dimension spanning decades; Thompson investigate some of the ways that construction can benefit from the principles of scientific management. Thompson's thesis asserts that task work is predicated on the accurate scientific management of work, including the "miscellaneous tasks". Thompson argues — as early as 1913 — that "…one may be challenged to find any class of work involving labor either indoors or out–of–doors where tasks cannot be fixed by proper time–study" [70].

Broken down in this way, work could grow to unprecedented scales, but the quality of the work would remain relatively variable [47]. Textile work being a salient example, it took time for workers to acquire sufficient skill to do every aspect of the work so that the garment would be accepted by the company soliciting that work [74].

A compelling solution emerged in the early 20th century to break tasks down into discrete, manageable routines that could be taught relatively easily, and whose work output could be evaluated in abstraction from the rest of the work [3]. In Ford's assembly line, this meant that workers were not responsible for building a whole car, but a single very narrowly defined action that needed to be done on every car [41]. By the mid–20th century, Schoenberger writes, "… the intensification of the labor process is argued to have hit mental, physical, and social limits." [58].

This approach, "Fordism" (and its better–known contemporary "Taylorism" of similar ethos), can be seen today in crowd work and on–demand labor through the application of micro–tasks. Teevan, Iqbal, and Veh highlight some of the advantages of breaking work into pieces, facilitating evaluation and parallelization [67]. By decomposing and recomposing tasks, and in particular by assigning similarly natured work to the same workers, workers could become "experts" in a small aspect of the work that they did, speeding their work dramatically [37]. Perhaps more important, however, was that the breaking down of work into tasks has made it more practical to evaluate work at each stage [54].

So how does this affect crowdwork?

The work we've seen so far

- worst case: assembling iPhones (extant)
- average case: railroad workers and assembly lines
- high (complexity) case:

[0] Cheng et al. found that microtasks — though not necessarily *faster* than "macrotasks" — yield higher quality work, particularly when that work is susceptible to frequent interruptions [10].

[0]

What forms of work design and worker management are viable?

- researchers have looked at how to increase worker productivity (e.g. finding the maximal speed at which gig workers can be expected to work before making errors) [9].
- we've also seen people "embrace error" [35].
- still other research has looked into ways to sandbox workers from the context of their work
- but scholarship looking into the design and management of work and workers isn't new; lots of research into getting pieceworkers to do work more quickly [59].
- Researchers have even asked the age old question of *what motivates* pieceworkers (echoing similar research on Wikipedia and Mechanical Turk) [56, 49, 31]

What will work and the place of work look like for workers?

The metaphorical mechanics of these dynamics are still at play; workers and managers continue to interact in adversarial manners, despite substantive work into aligning the motivations of workers and requesters

The existing body of research has shed light on on–demand labor from various perspectives, and revealed a number of topics that, through our framing, are clearly situated together. Those topics are, at a high level, as follows:

1. the **processes** involved in making work into tasks, or discretization;
2. the outcomes (and indeed the **fallout**) of that discretization, both on the work itself as well as the workers; and finally
3. the **relationships** between workers and requesters of the work — both *cooperative* and *adversarial* cases.

The Fallout of Crowd Work

Irani and Silberman point out the disillusion that companies such as Amazon foster on platforms for work like AMT (see also Salehi et al.'s work continuing in the spirit of this observation to generate collective action to improve worker conditions) [30, 57]. Lee et al. find similarly that workers on gig work platforms are frustrated by the systems on which they work, to say little of the policies which these systems enforce [38].

We discussed the benefits of flexibility (both in the sense of having arbitrary workers perform tasks and in the sense that we can design tasks to be more resilient to poor work) in the previous section. It's from that point in the literature that we turn our attention to the perhaps unintended effects of crowd work and the affordances for transience that we build into this mode of work. We'll address two major areas of work under this subject: 1) Low Pay; and 2) Variable quality work.

Low Pay

Horton and Chilton identified problems with crowd work wages relatively early on, attempting to address this imbalance from a behavioral economic perspective — that is, identifying and presenting a model that describes a worker's "*reservation wage*" [24]. This work has largely informed much of the research into and practice of estimating crowd work compensation [60, 50].

But we turn to Irani and Silberman's discussion of "*Turkopticon*", a system they designed to interrogate worker invisibility and to promote better wages across several dimensions [30]. Of particular relevance here, Irani and Silberman call to attention that "Turkers" are ultimately vulnerable to wage theft and pay rates that translate to well under minimum wage. Returning to Horton and Chilton, we find that the median "reservation wage" in 2010 was $1.38, while the mean was $3.63 [24].

Understanding workers' motivations given these conditions has thus become a goal for some researchers [5]. Sun, Wang, and Peng conclude that "… solvers participate in online tasks not only for

money but also for enjoyment or the sense of self–worth" [66]. This might have rung true in 2011, and certainly corroborates Ross et al.'s findings after investigating "who are the crowdworkers", but as Silberman points out "we [have since] learned that most tasks on AMT are done by a small group of professional Turkers…" [55, 62].

Now, Irani and Silberman and later Salehi et al. cite insufficient pay as a central point of frustration among workers, via Irani and Cushing's contributions in this space [57, 28, 14, 30].

On–demand workers were not the first to be exploited along the dimension of low pay rates. Frustration over low (and declining) pay was one of the chief grievances among then nascent British labor unions in the early 20th century [72]. This, Ebbinghaus and Visser argued, fueled the rocketing union membership rates through the mid–20th century until 1980 (to which we'll return when we discuss Levi et al.'s reexamination of labor unions) [15, 40]. This realization has similarly fueled a body of research into the various incentive structures available to piecework employers [56].

The parallels between the complaints of low pay among crowd workers and other on–demand workers and the pieceworkers and later factory workers in the 20th century are inescapable. We argue further that the *causes* here — work decomposition, work abstraction, and flexibility — lead inexorably to low and declining pay for workers. Moreover, we point out that low pay leads to other negative outcomes both in on–demand work as well as in piecework and on assembly lines.

Variable quality work

Researchers have struggled with what we might generously call work of "variable quality" along two dimensions. The first, to use the characterization of one of these contributions, we can call "understanding malicious behavior" [17]. While some work has cast workers as "malicious" or at least adversarial parties, the evidence thus far suggests that workers behave in unexpected ways as they attempt to assert some control over their interaction with the system (a topic of discussion to which we'll return later) [38]. The second dimension of research in this space generally attempts to eke out the highest quality work possible from workers given the apparent difficulty in predicting work outcomes [35].

The effect low wages have had on piece work and factory workers is well–known; Gantt discuss this exact mechanism in his book on "… where there is no union, the class wage is practically gauged by the wages the poor workman will accept, and the good workman soon becomes discouraged and *sets his pace by that of his less efficient neighbor*, with the result that the general tone of the shop is lowered" (emphasis added) [18].

This research is similar to, but subtly different from, the notion of the "market for 'lemons"' which Fort, Adda, and Cohen discuss; specifically, Akerlof's writing of a "market for 'lemons"' describes a marketplace where the quality of the product or service is unknown to the buyer [16, 1]. The effect of this *perceived* uncertainty is that the *actual* trustworthiness drops precipitously as all of the consistent, reliable, high–quality workers capable of leaving these markets do so, leaving only the ones who cannot or will not establish their trustworthiness.

Relationships Between Workers and Managers

Suffice it to say that poor pay and poor work are linked, and that we should not be surprised to find this relationship play out online as strongly as it does offline. But the poor treatment of workers by managers — both human and algorithmic — do more than affect the economic relationships between workers and employers. Here, then, we turn to examine this facet of on–demand work and how these dynamics strikingly replicate the relationships researchers in labor advocacy encountered in the study of piecework and factory work.

This topic can be condensed into two major areas: 1) external (scientific) management, and the evaluation of workers as functional modules; and 2) the consequential resistance workers express due to their perceived alienation and distance from managing forces.

External Management

We discussed Fordism and Taylorism earlier in our discussions of finding crowdwork's limits and worker volatility, but here the core of these paradigmatic views — the scientific management of work — becomes relevant. We use "external" here instead of "scientific", however, to more broadly capture the disconnect between managers and workers. By describing it as thus, we can touch on the relationship that workers have with *researchers*, as well, even though that work is not strictly — or just not exclusively — of the same nature as the management and experience as when interacting with requesters.

First, intuitively, the variable–quality work we discussed previously has led to a large and growing body of research attempting to evaluate workers' performance and error rates across numerous dimensions; for example, Cheng, Teevan, and Bernstein explore the error rates of workers by operating on a sliding scale giving workers varying amounts of time to accomplish micro–tasks [9]. Irani and Silberman describe the treatment of workers as sorts of "human APIs" that can, importantly, be rigorously evaluated [29]. Gevins and Smith began to explore the neurophysiological effects of cognitively demanding tasks on workers, informing crowdsourcing research by suggesting the use of cognitive load assessments such as NASA Task Load Index surveys to evaluate workers pre and post–tasks [35, 9].

External management comes in other forms than scientific, as previously mentioned. Researchers in particular have noticed that their relationships with on–demand workers are, at the least, complex. Irani and Silberman point out that their relationships with Turkers are highly complex; specifically, their interactions with field sites in which they work as designers and mediators of change influence the relationships they have with Turkers [29].

The scientific management of pieceworkers has been well–studied under the umbrella of assembly line research, and even physiological study of pieceworkers closely resembles the research into cognitive loads and stress levels that we discussed among on–demand crowd workers [25, 6]. Even the complicated relationships between observers and workers themselves are not necessarily new; Riis's photodocumentary of pieceworkers has even been re–examined through an exercise asking crowd workers to photograph themselves for similar purposes as Riis's — to document and humanize an otherwise abstracted, invisible workforce [2, 30, 53].

Similarly, Pollard's words on the punishment factory workers faced — for example, that "unsatisfactory work was punished … by fines or by dismissal" — seems especially relevant given the fears we now know to be ubiquitous on platforms such as AMT, Uber, and other on–demand markets [51, 38, 57, 30, 46].

Resistance

It shouldn't surprise us, then, that workers have resisted the management imposed on them both by other people and their systems, often without recourse or opportunity for feedback, let alone substantive input. Indeed, Lee et al. discover of Uber drivers that many toggle their availability to avoid being dispatched to more distant locations, resisting the intent of the designers of the systems and their "algorithmic and data–driven management" [38].

Resistance has sometimes been more coordinated, as well; we see this in Irani and Silberman's coverage on *Turkopticon* as workers collectively accumulated information about requesters, and in Salehi et al.'s work on *Dynamo*, which generated "Guidelines for Academic Requesters" written by crowd workers [30, 57].

Resistance against managers in piecework and factory labor settings are deeply well–explored, but perhaps the most relevant case study to draw on here is to be found in Waldinger et al.'s case study of "Justice for Janitors", where marginalized workers managed to raise awareness for their plight and secure support for badly needed reforms [75]. The achievements of labor advocacy groups such as labor unions as resistant, even adversarial organizations counter–balancing the management is somewhat well–understood [22, 13]. We argue that these threads of resistance against management in various forms are in fact one.