Should Robots or People Do These Jobs?

A Survey of Robotics Experts and Non-Experts About Which Jobs Robots Should Do

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***Abstract*—This study builds upon previous work regarding people's attitudes toward robot workers, identifying the characteristics of occupations for which people believe robots are qualified and desired. This research updates prior research and adds a new dimension of respondent expertise in the domain of robotics (*N*=392, which includes 134 robotics experts and 258 non-experts). We deployed a web-based survey that asked respondents about their attitudes toward robots' suitability for a variety of jobs (*n*=812) from the U.S. Department of Labor's O*NET occupational information database. There were different responses from experts and non-experts about what types of jobs robots: (a) could, but should not do and (b) should, but could not do. Implications for the robotics community are discussed.**

Keywords- Human-robot interaction; HRI; robots; occupations; jobs; attitudinal survey; experts

I. INTRODUCTION

To develop robots that everyday people will accept, adopt, and actually use, robotics experts must be mindful of what it is that people want out of their interactions with robots. Our prior research indicates that people are interested in having robots perform jobs that require memorization, keen perceptual abilities and service-orientation–cognitive and social factors [18] that go beyond the typical heuristic of "dirty, dangerous and dull." The inconsistency could be explained in many ways: perhaps robotics experts have more insights into what robots are and are not capable of; perhaps robotics experts are not cognizant of what everyday people actually want; or perhaps robotics experts have more complicated goals in mind than can be summarized in a simple catchphrase. It is desirable to develop a richer understanding of what it is that robotics experts and everyday people think that robots could or should do as a basis for deeper discussions about what tasks we all believe that robots can and should do.

In this study, we measured public attitudes towards robot workers—this time surveying both robotics expert and non-expert attitudes on robot work so that we could specifically compare the two. In previous work [18], we deployed a public-opinion survey that asked people the degree to which they felt specific jobs would be best performed by a robot or by a human. By analyzing which job characteristics best predicted the user responses, we were able to develop a complex model of what work characteristics people felt were uniquely suited to robots or humans. The current study updates this line of research, asking the same questions of experts and non-experts in order to look specifically at the insights and biases that robotics experts might have about robots doing human jobs. We naturally expect the opinions of robotics experts to differ from that of the general population due to their knowledge of the overwhelmingly industrial occupations that utilize robots today [10] and because of their proximity to the topic, but are curious what specific revelations might surface.

II. RELATED WORK

Robots are commonly depicted in the popular media as being service or entertainment-oriented, whereas most robots today are deployed in industrial applications in the automotive, petrochemical [7], electronics, metalworking and food sectors. Based on these differences in availability [20], it would be reasonable to expect that robotics experts would have different views and predictions on appropriate robot occupations than the wider population.

While no prior studies have surveyed robotics experts on their views of robots, their views can be inferred through the metrics they use to evaluate them. In their survey on evaluation metrics for robots, Steinfeld, et al. identified navigation, perception, management, manipulation and social as the key dimensions of robot capabilities [16]; they mention that, by and large, robots are designed for specific tasks, and so evaluation metrics are highly partitioned and application-specific. Robots that are oriented towards "consumer use" in the service or entertainment sectors are treated as specialized categories of "sociable" [1] or "socially interactive" [4] robots, which differ from their industrial brethren in being designed with factors such as "humanness" and "persuasiveness" in mind.

Previous studies examining children's attitudes towards different robot designs [23], humanness in robot evaluation [3], and negative attitudes towards robots [14] focus on robot appearance as the operant variable that influences beliefs about robots. Such studies show that people who are surveyed about appropriate robot capabilities activities can be strongly influenced by the presentation of robot forms that are matched or mismatched to the proposed function [5]. It is possible that people's attitudes towards robots in these studies are influenced by the match or mismatch between the demonstrated robotic form and the implicitly proposed robotic function. We are interested in attitudes about robots being introduced to a variety of occupations in general [19], and not in opinions about any variety of robots in specific.

In fact, people's attitudes about whether robots could or should perform specific kinds of work might reveal a lot about what they think robots are. Popular conceptions of robots are strongly influenced by science fiction, and are evaluated almost exclusively in reference to human tasks and capabilities [8]. In an open-ended study of what types of activities people believed a humanoid in-home robot would do, Copleston and Bugmann [2] found that people would ask such robots to do jobs such as housework, food preparation and personal service. They also found that people envisioned such robots not only alleviating people from work around the house (90% of responses), but also to serve as a source of personal entertainment (10% of responses). This suggests that everyday people expect robots to have general-purpose and multifunctional capabilities, which might outstrip the expectations that roboticists have for their own creations.

Another source of potential differences between expert and everyday attitudes towards robots is proximity; experts should like robots more because they are around them more. Previous research suggests that working on an object (e.g., a pet rock) can create a sense of self-extension into the object [9]. Current research suggests that working on a robot has a biasing effect that causes people to feel more attached to the robot [6]. Based on this consideration, it would be unsurprising if experts had a more optimistic estimation of what robots could or should do.

III. Study Design

The primary research questions in this investigation were:

(Q1) *Do robotics experts hold different beliefs than non-experts about whether and which jobs robots could and should do? Do other demographic differences influence these beliefs?*

(Q2) *What occupational dimensions influence expert and non-expert attitudes toward robots doing human jobs?*

(Q3) *What types of jobs do people believe robots (a) could, but should not do? And, (b) should, but could not do?*

A. Working Hypothesis

We did not set formal hypotheses for how experts and non-experts would compare against each other because this was an exploratory analysis. We chose to use this opportunity to inform research hypotheses for future work. Based upon previous work with everyday people (i.e., non-experts) [18], we investigated two hypotheses:

(H1) People will feel different about robots doing occupations *with* people in comparison with robots *replacing* people.

(H2) People will differentiate between their attitudes about what occupations robots *could do* versus what they *should do*.

To test these hypotheses, we conducted an online survey of both robotics experts and non-experts to gauge people's attitudes about whether different jobs should be done by people or robots. In addition to recruiting respondents from different populations to explore the influence of expertise level (expert vs. non-expert), we also varied the framing of the scale midpoint ("either people or robots" or "both people and robots") to imply competitive and collaborative human-robot work scenarios from Hypothesis 1. We also structured the survey so that it asked both whether robots could and should do each job (within-respondents) for Hypothesis 2; to address ordering concerns, we balanced the order of response options (people first or robots first).

B. Respondents

This study combined previous data on non-expert responses about what types of occupations non-experts believe robots could and should do with new data from experts in robotics, collected during the years 2008-2010.

The experts data set included 134 human-robot interaction and robotics expert respondents (21 women, 112 men, and 1 unreported gender), who were recruited through human-robot interaction and robotics-worldwide mailing lists. They also occupied a comparably wide range of ages (*M*=32.86, *SD*=9.28) as in the original data set. Based on a reverse look-up of the respondents' IP addresses, there were 66 respondents from the Americas, 45 from Europe, 14 from Asia, and 9 from Australia. Though some of the experts may have been familiar with the preceding study [18], they were not informed about the hypotheses of this new study prior to their participation in the survey.

The non-experts data set included 258 respondents (105 women, 86 men, and 67 unreported gender) with a wide range in ages (*M*=32.19, *SD*=10.95), jobs, and educational levels, who were recruiting through Mechanical Turk [11], an online service for soliciting and completing human intelligence tasks. We used the O*NET job database for the demographic job selection memo; the occupational category breakdown of the non-expert respondents is listed in Table 1. None of the survey respondents indicated that they had jobs that had to do with studying, designing or testing robots (based on the occupational description of the jobs). Based on reverse look-up of the respondents' IP addresses, there were 203 respondents from the Americas, 26 from Europe, 21 from Asia, 4 from Australia and New Zealand, and 3 from the Middle East.

C. Materials

We used the O*NET database (version 11) from the U.S. Department of Labor [15][21] as an exhaustive source of 812 human jobs names, job descriptions and ratings of those jobs

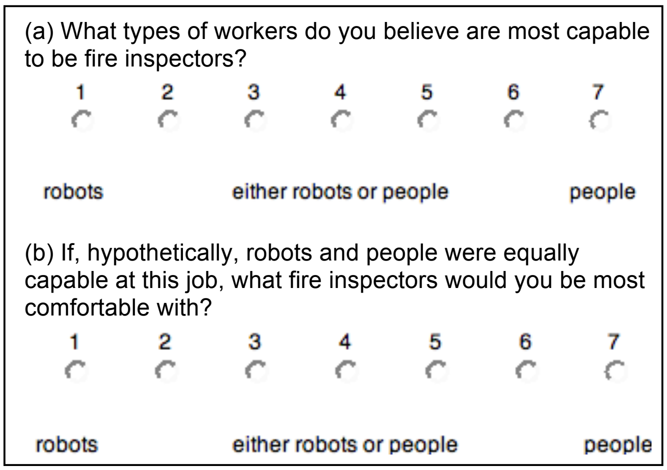
Table 1. Occupations of surveyed non-experts (*N*=258)

Occupational category	#	%
Decline to state	53	20.5
Computer and Mathematical	34	13.2
Arts, Design, Entertainment, Sports & Media	19	7.4
Student	19	7.4
Management	17	6.6
Office and Administrative Support	16	6.2
Educational, Training & Library	15	5.8
Business & Financial Operations	13	5.0
Sales & Related	11	4.3
Other	61	23.6

along a hierarchy of 277 occupational dimensions. Although there are newer versions of this database, we chose to use version 11 in order to be consistent with prior work [18]. We created an online questionnaire to collect survey responses. Randomly ordered sets of the 812 O*NET jobs were parceled out successively, 28 per survey respondent, so that we would ideally have a uniform number of ratings per job and so that no respondent would see any job more than once.

D. Procedure

Each respondent for our survey was asked to rate whether each of their 28 jobs would be better performed by people or robots, using a seven-point scale. Each entry consisted of an O*NET occupation name (e.g., Fire inspectors), the O*NET occupation description (e.g., Inspect building and equipment to detect fire hazards and enforce state and local regulations), and two questions about that occupation: (a) what kind of worker could do the job and (b) assuming that both types of workers could do the job, what kind of worker should do the job.


(a) What types of workers do you believe are most capable to be fire inspectors?

1 2 3 4 5 6 7

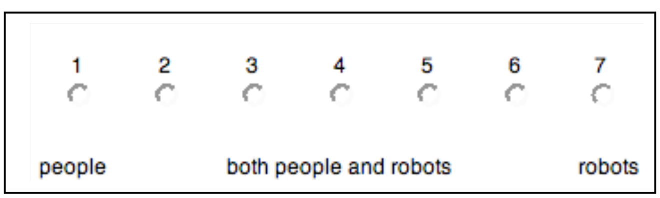
robots | either robots or people | people

(b) If, hypothetically, robots and people were equally capable at this job, what fire inspectors would you be most comfortable with?

1 2 3 4 5 6 7

robots | either robots or people | people

There were four variations for the scale anchors. The preceding example shows the condition where the midpoint anchor is "either robots or people" and the end anchors with robots presented before people (OR + ROBOTS TO THE LEFT). The following example is from the AND + PEOPLE TO THE LEFT condition:


1 2 3 4 5 6 7

people | both people and robots | robots

Demographic questions were asked at the end of the survey.

E. Measures

The primary dependent variables in this study were the seven-point ratings of how much people believed robots could and should do each of the occupations. This data was cleaned to exclude responses from respondents that did not finish the study or who seemed (based on IP address) to have done the study multiple times. The cleaned data was subsequently organized for analysis in two ways.

Table 2. Repeated Measures ANOVA Results for Manipulated Variables (*N=392* respondents)

Variables and interactions	*df*	*F*	*p*
Between: EXPERTISE	1	4.38	.037*
Between: AND/OR	1	9.37	.002**
Within: COULD/SHOULD	1	0.29	.59 (n.s.)
EXPERTISE x AND/OR	1	1.17	.28 (n.s.)
EXPERTISE x COULD/SHOULD	1	2.20	.14 (n.s.)
AND/OR x COULD/SHOULD	1	2.14	.14 (n.s.)
EXPERTISE x AND/OR x COULD/SHOULD	1	1.01	.32 (n.s.)

*p<.05, **p<.01

To assess how individual differences affected general assessments of whether people or robots could and should perform human jobs, we looked at the mean values of the could and should ratings across the 28 jobs for each respondent.

To understand how aspects of specific jobs affected respondent's assessments about whether the job could and should be performed by people or robots, we calculated mean responses across respondents for each occupation, separating ratings for experts from non-experts.

IV. ANALYSES

A. Manipulated Variables

To investigate the two hypotheses that (H1) there should be a main effect of AND/OR, (H2) there should be a main effect of COULD/SHOULD wording, we ran a mixed repeated measures analysis of variance (ANOVA) with COULD/SHOULD as a within-respondents independent variable and EXPERT/NON-EXPERT RESPONDENT and AND/OR as between-respondents independent variables. Individual respondents were the unit of analysis in this data analysis. This data was organized by individual respondents' mean ratings (i.e., averaged across each of their 28 ratings) rather than by occupation median ratings (i.e., median of ratings from several individuals), i.e., individual respondents were the unit of analysis.

B. Individual Differences

Because there could be individual differences (i.e., differences between people) that could influence people's ratings of what they believed robots could and should do, we analyzed the data in terms of some individual difference variables such as gender (FEMALE vs. MALE) and research community (HRI vs. ROBOTICS-WORLDWIDE). Individual respondents were the unit of analysis.

C. Occupational Dimensions

We used a variable-based approach [13] to identify the underlying dimensions of occupations that predict their mean Likert responses. We used forward stepwise regression analyses to see which occupational dimensions from the O*NET database would rise to be significant contributors to the overall linear regression model. Forward stepwise analysis was used because it is useful for exploratory analyses such as these [17]. Missing values were treated by mean substitution. Occupations were the unit of analysis.

D. Should, but Could Not, and Could, but Should Not

After we ran the linear regression to see what occupational dimensions predicted what types of jobs experts and non-experts thought robots could and should do, we ran a forward stepwise linear regression on the difference between SHOULD and COULD ratings for each occupation to see what occupational dimensions predicted differences in what people believed robots could, but should not, and should, but could not, do.

Then we identified the top three occupations that the respondents believed robots should, but *could not*, do. We calculated difference scores for each occupation in the data set (SHOULD rating minus COULD rating). To see what occupations the respondents believed robots could do, but *should not* do, we used the same difference scores from the previous analysis. These analyses were also run on the expert and non-expert respondent data sets separately, using occupations as the unit of analysis.

V. RESULTS

A. Manipulated Variables

To address hypotheses 1 and 2 (main effects for AND/OR and COULD/SHOULD) we ran repeated measures ANOVA. For the summary of statistical analysis results, see Table 2.

AND/OR affected people's ratings of how appropriate it would be for robots to do the human occupations, $F(1,920.8)=9.37$, $p<.01$, such that people were more likely to be in favor of robots doing the occupations if they were doing the jobs in place of people (OR, $M=4.14$, $SE=0.08$) as opposed to doing jobs with people (AND, $M=3.79$, $SE=0.08$). Thus, Hypothesis 1 (that AND/OR wording would affect responses) was supported by these data, but the direction of this effect was the opposite of the results found in previous work [18] that only included non-robotics-experts.

Hypothesis 2 (that COULD/SHOULD wording would affect responses) was not supported by this data analysis, $F(1,204.3)=0.29$, $p=.59$ (n.s.).

Our open ended research question of whether or not robotics expertise level affects beliefs about what robots could and should do brought us to analyze robotics expertise as an independent variable. Robotics experts were more inclined toward robots doing human occupations ($M=4.09$, $SE=0.09$) than non-experts ($M=3.84$, $SE=0.07$), $F(1,920.8)=4.38$, $p<.05$.

None of the two-way or three-way interaction effects were found to be significant predictors of beliefs about what human occupations robots could or should do.

B. Individual Differences

To test for other demographic effects, especially gender (female vs. male) and robotics community (human-robot interaction vs. robotics-worldwide mailing lists), we re-ran the previous data analysis, but added in each of these demographics as new independent (between-respondent) variables.

Gender was not found to be a significant predictor of people's beliefs about what robots could and should do, $F(1,723.8)=1.94$, $p=.16$ (n.s.). Similarly, robotics community was not a significant predictor of people's beliefs about what robots could and should do, $F(1,250.3)=.83$, $p=.36$ (n.s.). None of the interaction effects were statistically significant.

C. Occupational Dimensions

1) Robotics Experts' Beliefs About What Robots Could Do

The regression analysis for what occupational dimensions predicted what robotics experts believed robots could do ran through 8 models before it stopped gaining significant improvements to the model fit (final model $F(8,802)=5.79$, $p<.001$, goodness of fit $R^2=.06$). The final model's predictors included the occupational dimensions presented in the top half of Table 3.

The robotics experts in our survey sample believed that robots could do better than people at jobs that placed high importance upon the ability to see details at a distance, perceptual speed[1], being dependable, and having knowledge of food production techniques and equipment[2]. They believed that people could do better than robots at jobs that required far vision skills, and the ability to visually discriminate between colors.

2) Robotics Experts' Beliefs About What Robots Should Do

The regression analysis for what occupational dimensions predicted what robotics experts believed robots should do ran through 12 models before it stopped gaining significant improvements to the model fit (final model, $F(12,802)=7.166$, $p<.000$, goodness of fit $R^2=.10$). The final model's predictors included the occupational dimensions presented in the bottom half of Table 3.

These robotics experts believed that robots should do jobs that involve guiding, directing, and motivating subordinates through "setting performance standards and monitoring performance"; speaking clearly; thinking creatively[3]; having the ability to re-categorize things in different ways; being dependable; and having knowledge of building and construction materials, methods, and tools. They believed that people should do jobs that involved interpreting the meaning of information, working in cramped workspaces, required negotiating with people and reconciling differences, involved the ability to coordinate multiple limbs simultaneously, required a willingness to take initiative (including taking on responsibilities and challenges), and having artistic interests.

[1] Perceptual speed is "the ability to quickly and accurately compare similarities and differences among sets of letters, numbers, objects, pictures, or patterns. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object." [15]

[2] Food production requires "knowledge of techniques and equipment for planting, growing, and harvesting food products (both plant and animal) for consumption, including storage/handling techniques."

[3] Thinking creatively requires "developing, designing, or creating new applications, ideas, relationships, systems, or products, including artistic contributions."

Table 3. Summary of Forward Stepwise Linear Regression Analysis of Occupational Dimensions Predicting Robotics Experts' Attitudes Toward Robots Or People Doing Human Work (*n*=812 occupations)

	VARIABLE	STANDARDIZED COEFFICIENT (*B*) AND SIGNIFICANCE
Experts COULD	Far Vision (Importance)	.34*
	Perceptual Speed (Importance)	.12*
	Dependability	.09*
	Food Production (Importance)	.08*
	Far Vision (Level)	-.22*
	Auditory Attention (Importance)	-.15**
	Initiative	-.13**
	Visual Color Discrimination (Level)	-.10*
Experts SHOULD	Guiding, Directing, and Motivating Subordinates	.23***
	Speech Clarity (Importance)	.17*
	Thinking Creatively (Importance)	.17**
	Category Flexibility (Importance)	.16**
	Dependability	.14**
	Building and Construction Knowledge (Importance)	.08*
	Interpreting the Meaning of Information (Importance)	-.31***
	Cramped Workspace and Awkward Positions	-.17***
	Negotiation (Level)	-.14*
	Multi-limb Coordination (Level)	-.13*
	Initiative	-.13**
	Artistic Interests	-.11**

*p<.05, **p<.01, ***p<.001. Shaded rows indicate factors where robots are preferred over people; in unshaded rows, people are preferred.

3) Non-expert Beliefs About What Robots Could Do

The regression analysis for what occupational dimensions predicted what non-experts believed robots could do ran through 5 models before it stopped gaining significant improvements to the model fit (final model $F(5,806)=7.07$, $p<.001$, goodness of fit $R^2=.04$). The final model's predictors included the occupational dimensions presented in the top half of Table 4.

Non-expert respondents believed that robots could do better than people at jobs that involved enterprising occupational interests[4], place importance upon the use of computers and electronics, and involve cooperation. They believed that people could do better at jobs that involved memorization skills as well as customer and personal service.

4) Non-expert Beliefs About What Robots Should Do

The regression analysis for what occupational dimensions predicted what non-experts believed robots should do ran through 2 models before it stopped gaining significant improvements to the model fit (final model $F(2, 809)=11.24$, $p<.001$, goodness of fit $R^2=.03$). The final model's predictors included the occupational dimensions presented in the bottom half of Table 4.

These non-experts believed that robots should do jobs that involved enterprising occupational interests and require being dependable (i.e., reliable, responsible, and fulfilling obligations).

Table 4. Summary of Forward Stepwise Linear Regression Analysis of Occupational Dimensions Predicting Non-Experts' Attitudes Toward Robots Or People Doing Human Work (*n*=812 occupations)

	VARIABLE	STANDARDIZED COEFFICIENT (*B*) AND SIGNIFICANCE
Non-experts COULD	Enterprising	.16***
	Computer and Electronics (Importance)	.13**
	Cooperation	.10**
	Memorization (Level)	-.14**
	Customer and Personal Service (Importance)	-.09*
Non-experts SHOULD	Enterprising	.12*
	Dependability	.09*

*p<.05, **p<.01, ***p<.001. Shaded rows indicate factors where robots are preferred over people; in unshaded rows, people are preferred.

5) Robotics Expert Differences in Could vs. Should

The regression analysis for what occupational dimensions predicted what robotics experts believed robots could, but should not, and should, but could not, do ran through 8 models before it stopped gaining significant improvements to the model fit (final model $F(8, 802)=5.66$, $p<.001$, goodness of fit $R^2=.05$). See Table 5.

These robotics experts believed that robots should, but could not, do jobs that require a high degree of trunk strength[5]; involve operating mechanized vehicles such as forklifts, passenger vehicles, aircraft, or water craft; require lots of on the job training; where visual color discrimination is of much importance[6]; and where workers value being paid well in comparison with others.

Furthermore, these robotics experts believed that robots could, but should not, do jobs that involve a high degree of multi-limb coordination, have good working conditions, and involve environments with extreme lighting conditions (either too dark or too bright).

6) Non-expert Differences in Could vs. Should

The regression analysis for what occupational dimensions predicted what non-experts believed robots could, but should not, and should, but could not, do ran through 10 models before it stopped gaining significant improvements to the model fit (final model $F(10, 801)=5.49$, $p<.001$, goodness of fit $R^2=.06$). See Table 6.

The non-experts believed that robots should, but could not, do occupations that require response orientation importance[7], frequent telephone use, exposure to whole

[4] "Enterprising occupations frequently involve starting up and carrying out projects. These occupations can involve leading people and making many decisions."

[5] Trunk strength refers to "the ability to use your abdominal and lower back muscles to support part of the body repeatedly or continuously over time without 'giving out' or fatiguing."

[6] Visual color discrimination refers to "the ability to match or detect differences between colors, including shades of color and brightness."

[7] Response orientation refers to "the ability to choose quickly between two or more movements in response to two or more different signals (lights, sounds, pictures). It includes the speed

Table 5. Summary of Forward Stepwise Linear Regression Analysis of Occupational Dimensions Predicting Differences Between What Robotics Experts Believe Robots Could vs. Should Do (*n*=812 occupations)

	Variable	Standardized coefficient (*B*) and significance
Experts Should Minus Could	Trunk Strength (Level)	.13*
	Operating Mechanized Vehicles (Importance)	.12*
	On the Job Training	.12**
	Visual Color Discrimination (Importance)	.11**
	Compensation	.10*
	Multi-limb Coordination (Level)	-.30***
	Working Conditions	-.15*
	Extreme Lighting Conditions	-.13**

*p<.05, **p<.01, ***p<.001. Shaded rows indicate factors where robots should but could not perform a job; unshaded rows have factors where robots could but should not perform a job.

Table 6. Summary of Forward Stepwise Linear Regression Analysis of Occupational Dimensions Predicting Differences Between What Non-Experts Believe Robots Could vs. Should Do (*n*=812 occupations)

	Variable	Standardized coefficient (*B*) and significance
Non-Experts Should Minus Could	Response Orientation (Importance)	.17**
	Frequent Telephone Use	.15**
	Exposed To Whole Body Vibration	.14**
	Sound Localization (Level)	.13*
	Importance of Competition	.09*
	Spatial Orientation (Importance)	-.23***
	Exposed to Hazardous Equipment	-.17**
	Structured Work	-.11*
	Spend Time Sitting	-.11*
	Engineering &Tech (Importance)	-.08*

*p<.05, **p<.01, ***p<.001. Shaded rows indicate factors where robots should but could not perform a job; unshaded rows have factors where robots could but should not perform a job.

body vibration, an ability to tell the direction from which sounds originate, and a high importance placed on competition faced on the job.

Furthermore, the non-experts believed that robots could, but should not, do occupations that have spatial orientation importance, involve exposure to hazardous equipment, involve structured work[8], involve spending lots of time sitting down, and where engineering and technology are important.

D. *Should, but Could Not and Could, but Should Not*

The robotics experts believed that robots should, but could not, do the jobs of computer software engineers, financial analysts, and boilermakers[9]. The non-experts believed that robots should, but could not, do the jobs of earth drillers (except for oil and gas industries)[10]; motorboat mechanics; and crushing, grinding, and polishing machine setters[11].

The experts believed that robots could, but should not, do the jobs of furniture finishers, bus drivers for transit and intercity, and restaurant cooks. The non-experts believed that robots could, but should not, do the jobs of tree nursery workers, museum curators, and log graders and scalers[12].

VI. DISCUSSION

We began this exploration to identify variables that impact what people believe robots could and should do. First, we will first address each research question in turn. Then we will address each set of survey results in the following subsections.

(Q1) *Do robotics experts hold different beliefs than non-experts about whether and which jobs robots could and should do? Do other demographic differences influence these beliefs?*

We found that robotics experts do indeed hold different beliefs than non-experts about what types of jobs robots could and should do. We did not find that gender (male vs. female) and research community membership (HRI vs. robotics-worldwide) measurably influenced those beliefs.

(Q2) *What occupational dimensions influence expert and non-expert attitudes toward robots doing human jobs?*

Tables 3 and 4 present the occupational dimensions that predict what kinds of jobs robotics experts and non-experts believe robots could and should do.

(Q3*) What types of jobs do people believe robots (a) could, but should not do? And, (b) should¸ but could not do?*

Tables 5 and 6 present the occupational dimensions that predict what jobs robotics experts and non-experts believe robots could, but should not, and should, but could not, do.

A. *Manipulated Variables*

The hypothesis (H1) that AND/OR wording would affect responses was supported by these data. However, the direction of the effect is the opposite of what was found in previous work that only included non-experts [18],

with which the correct response is started with the hand, foot, or other body part."

8 Structured work refers to the extent to which a job is "structured for the worker, rather than allowing the worker to determine tasks, priorities, and goals."

9 Boilermakers "construct, assemble, maintain, and repair stationary steam boilers and boiler house auxiliaries."

10 Earth drillers "operate a variety of drills--such as rotary, churn, and pneumatic--to tap sub-surface water and salt deposits, to remove core samples during mineral exploration or soil testing, and to facilitate the use of explosives in mining or construction. May use explosives."

11 Crushing, grinding, and polishing machine setters "set up, operate, or tend machines to crush, grind, or polish materials, such as coal, glass, grain, stone, food, or rubber."

12 Log graders and scalers "grade logs or estimate the marketable content or value of logs or pulpwood in sorting yards, millpond, log deck, or similar locations."

suggesting that people now prefer robots to replace human workers rather than working with them. Hypothesis (H2) that COULD/SHOULD wording would affect responses was not supported by the data. While we do not have an explanation for the turnabout in H1, we note that the global economic climate of this study differs significantly from that of the previous study, so it is possible that a major change in attitudes has taken place. To be more certain, we intend to perform follow-up studies that look at AND/OR as a within-subjects factor much in the way we examined COULD/SHOULD in this study.

While experts were like non-experts in the way that they responded to the AND/OR wording, experts were generally more positive about robots doing human jobs than non-experts. We believe this indicates basic optimism about the need for and capability of robots to assist and/or replace people in their jobs.

B. *Individual Differences*

Because of the gender distribution differences between the two groups of respondent types (experts vs. non-experts), we were concerned that gender differences might confound expertise level differences. Therefore, we analyzed gender as its own variable in this data set. We did not find statistical support for the notion that gender influenced these respondents' beliefs about what kinds of jobs robots could or should do.

Another potential source of individual differences between expert respondents could have been the research community to which the respondents identified (i.e., subscribers to the mailing lists that we recruited from) because members of the HRI mailing lists could conceivably be more familiar with benefits and concerns regarding people working *with* robots than members of the robotics-worldwide mailing lists. However, we did not find statistical support for the notion that robotics community membership influenced these respondents' beliefs about what kinds of jobs robots could or should do.

C. *Occupational Dimensions*

In some ways, this study reveals the ways in which robotics experts might have a more nuanced sense of what robots are good at and bad at, as compared to non-experts. For instance, "dependability" is a predictive factor for both experts and non-experts in their SHOULD ratings. However, non-experts also prefer robots for jobs with high "enterprising" scores—high status jobs that require a lot of flexibility. Some of the predictive factors in the experts' regression analysis share some of the sentiments of robots being good for enterprising jobs; for instance, guiding subordinates, thinking creatively, and category flexibility. At the same time, the experts' regression also shows a host of reservations on this front, like a belief that robots have difficulty with interpreting the meaning of information, working in cramped workspaces, negotiation, and taking initiative.

The studies also suggest that robotics experts are more likely than non-experts to focus on an occupation's perceptual requirements in determining whether a robot COULD perform a task, whereas non-experts are more skeptical about the robot's ability to memorize domain knowledge or to interact sociably with customers.

D. *Should, but Could Not and Could, but Should Not*

The analysis of what jobs robots should but could not do, reveals the experts to be positive about robots performing highly compensated jobs but having concerns about the robots' sensory or physical capabilities. The non-experts, on the other hand, are interested in having robots undertake social tasks like responding to people or answering the phones. This suggests to us that experts might be mindful of the economic drivers behind robots being put into work, whereas non-experts are mostly thinking about how robots could serve them personally.

In the analysis of jobs robots could but should not do, both the experts and the non-experts seem to have both an urge to reject robots from comfortable jobs (where the working conditions are good, where there is a lot of sitting involved, and where work is highly structured) and also to protect robots from hazards (like extreme lighting conditions or hazardous equipment).

VII. LIMITATIONS

As with any single study, there are several limitations to the current work. These limitations were considered and balanced against the research goals and resources for the current study.

First, this survey's results are largely dependent upon the respondents who volunteered and completed the survey: It is likely that there are sampling biases in these data because of our modes of respondent recruitment, the use of English instructions and questions, and the use of American occupations for these questions. To minimize bias in the responses, potential respondents were not told the hypotheses of this current study. Another issue with this data set is the relatively small data set in comparison to large-scale national and international efforts to gauge public opinions. We hope that these results will motivate interest in a larger-scale survey.

Second, this survey's results are shaped by the design of the survey itself. We asked only closed-ended questions regarding attitudes toward robots doing human jobs because we wanted the study to scale up to larger sample of respondents than we could reasonably analyze if these had been open-ended responses. Follow-up surveys could potentially provide an even wider array of ideas for future jobs to pursue in human-robot interaction. In addition, multiple concerns about the fitness of jobs might be conflated by our study design; future studies may separate questions about how well a robot could do a job, how well a person could do that job, and how good that job might be for the people or robots working in them.

Third, the goodness of fit R^2 values are relatively low in comparison to well understood and thoroughly modeled phenomena. Ideally, the goodness of fit would be as close as possible to 1. Because this is an exploratory study with many potentially influential variables, we were not surprised by the relatively low R^2 values. We do not yet have a thorough model of exactly what variables influence what occupations people believe that robots could and should do. In many domains that have a rich complexity of influential factors (e.g., predicting stock returns), R^2 values around 0.05 are not uncommon.

VIII. FUTURE WORK

This study presents the second round of data and analyses for exploring the questions surrounding what kinds of work people believe robots could and should do. There is still much more to be done in more specific task-level analyses (as opposed to occupational-level), more specific industries (e.g., focusing upon manufacturing or service industries as opposed to all industries altogether), more specific geographical regions of the world, other taxonomies of occupations (that could differ from country to country), other time frames (current jobs vs. the future) and in more languages (not only English). The goal of this line of work is to provide examples of how one could go about exploring the possibilities for applying robotic technologies to the spaces where both end-users and robotics researchers and developers actually want to put robots. Thus, these methods and analyses were presented so that others could replicate this work in more diverse or more focused domains.

There is also more work to be done in the space of individual differences in attitudes towards robots being used in society. Going beyond demographics such as gender, age, education level, etc., one particular individual difference stands out as being potentially powerful—anthropocentrism. Anthropocentrism refers to "the tendency of individuals to perceive the world from a human-centered perspective, in which humankind is the most significant of all entities" [12]. This concept has been studied with respect to computers, not robots, in the past [12], and was the initial inspiration for this trajectory of research [18]. There are many other individual, cultural, and organizational factors that will likely influence people's attitudes towards robots taking on jobs that are currently done by people, which make this an incredibly rich and potentially fruitful area of future research.

IX. CONCLUSIONS

This work has extended previous work on attitudes toward robots doing human jobs [18] and further supports the notion that occupational dimensions of human jobs can be used to investigate attitudes toward robot workers.

Our intent for this study was multifold; to establish benchmarks of current attitudes about robot capabilities in the population of robotics experts and non-experts, to highlight difference between these communities so that robotics experts might both understand their own biases and better relate to the interests and concerns of customers and other end-users who might interact with robots, and to stimulate dialogue about what occupational applications are targeted when we work on specific robot technologies.

Because of the differences between robotics experts' and non-experts' attitudes towards what type of jobs robots should do, it is important for robotics researchers to better understand their potential end users, who may not be robotics experts. It is equally important to understand what potential end-users of robots want and do *not* want their robots to do.

ACKNOWLEDGMENTS

Our thanks go to the HRI and robotics-worldwide research communities for their participation in the survey. We also thank Clifford Nass and David Grusky for their advice on the early stages of this research.

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